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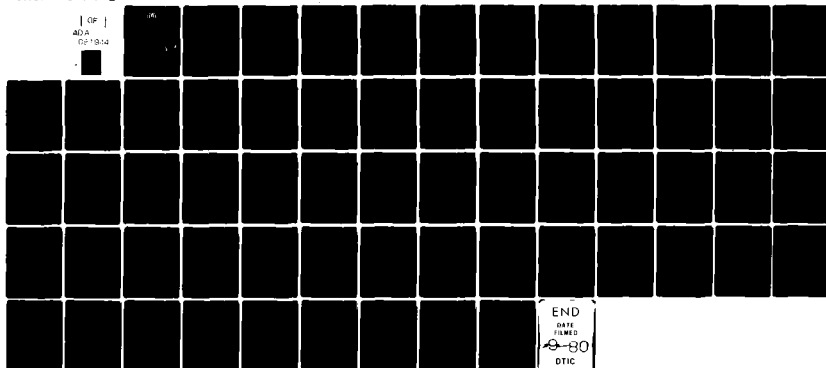
NORTHEASTERN UNIV BOSTON MASS ELECTRONICS RESEARCH LAB F/6 22/2  
COMMUNICATION AND INSTRUMENTATION SYSTEMS FOR SPACE VEHICLES.(U)  
JAN 80 J S ROCHEFORT, L J O'CONNOR F19628-76-C-0111

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COMMUNICATION AND INSTRUMENTATION

SYSTEMS FOR SPACE VEHICLES

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FINAL REPORT

12 January 1976 through 30 November 1979

1 January 1980

Approved for public release: distribution unlimited

Prepared for

AIRFORCE GEOPHYSICS LABORATORY  
AIR FORCE SYSTEMS COMMAND  
UNITED STATES AIR FORCE  
HANSCOM AFB, MASSACHUSETTS 01731

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFGL-TR-80-0189	2. GOVT ACCESSION NO. AD-A087944	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) COMMUNICATION AND INSTRUMENTATION SYSTEMS FOR SPACE VEHICLES		5. TYPE OF REPORT & PERIOD COVERED Scientific - Final (12 Jan. 76-30 Nov. 79)
6. AUTHOR(s) J. Spencer/Rochefort Lawrence J./O'Connor Norman C./Poirier		7. PERFORMING ORG. REPORT NUMBER
8. CONTRACT OR GRANT NUMBER(s) F19628-76-C-0111		
9. PERFORMING ORGANIZATION NAME AND ADDRESS Northeastern University Electronic Research Laboratory Boston, Massachusetts 02115		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62101F 7659D1A1
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory Hanscom AFB, Massachusetts 01731 Monitor/Eben M. Hiscock/LCR		12. REPORT DATE 1 January 1980
13. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		14. NUMBER OF PAGES 61
15. SECURITY CLASS. (of this report) Unclassified		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES  Tech, other		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Calibrators, converters, airborne television, PCM, encoders, commutators, Ground based radiometer, airborne photometer, Rocket and balloon instrumentation systems, Field Support. Component evaluation, batteries		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report summarizes the main work carried out under this contract (January 12, 1976 through November 30, 1979). Contract effort can be grouped under airborne and ground support instru- mentation systems, rocket and balloon field programs, and evaluation testing of commercial telemetry components. Instrumentation systems developed have included pre-flight		

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calibrators, ground-based radiometers, airborne photometers, airborne television, a PCM encoder and a commutated-umbilical ground check-out system. Rocket field programs have been involved with HIRIS, multi-E-fields,  $LN_2$  interferometers, composition technology, payload dynamics, field widened interferometers, the ECLIPSE '79 program, a post burn-out thrust experiment and an eschelle spectrometer. Balloon field programs have been concerned with an airborne photometer, the BAMM program and an extreme ultra violet experiment. Brief mention is given to the components tested under an evaluation program concerned with such airborne components as, voltage controlled oscillators, VHF and UHF transmitters and lithium batteries.

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## INTRODUCTION

This report summarizes the work which has been carried out under this contract. Effort began on January 12, 1976 and a certain amount of the initial effort followed-on from the previous contract (which ran through March 31, 1976). Although much of the work output was related on a project basis, the chapters of this report have been organized to group the effort under such categories as development programs, airborne instrumentation, field support and testing and analysis programs. The report has been divided into three chapters.

The first chapter deals with development programs and as such contains the bulk of the work which required applied research, system conception, engineering development and original design of circuits. This work led to one scientific report, one presented paper, one AFGL technical memorandum, one master's thesis and one in-house report.

The second chapter deals with airborne instrumentation systems flown on sounding rockets and high altitude balloons. This chapter is concerned with programs and their field support. Some of the instrumentation discussed was developed during this contract period and is discussed in Chapter I. Some of the instrumentation was developed under previous contracts. Many of the airborne systems are predominantly composed of off-the-shelf type commercial components. In just about every instance wiring lay-outs, minor circuits and block-house control panels were required but detailed discussion is omitted from this report because of the relatively routine nature of this work.

The final chapter of this report is concerned with components testing programs and computer analysis programs. The component testing program



has been existence during previous contracts and in two scientific reports during this contract period. The battery evaluation program was initiated during this contract and should probably be continued in the future as new cell types are as yet not completely predictable in their long-term performance.

## CHAPTER I

### DEVELOPMENT PROGRAMS

#### A. Preflight Calibrator

Scientists have always had misgivings concerning any components or circuits which are located in the signal path between the scientific instrument and the telemetry system and which have the capability of interrupting this connection, such as an inflight calibrator. This concern is not completely without justification. It can be somewhat disconcerting to receive calibration signals for an entire flight. On the other hand, the scientist in his quest for more accurate data, would like to have the data transmission path calibrated as close as possible to the time in which his data will be taken. A compromise between the extremes of calibration made before vehicle buildup and calibration made by an inflight calibrator is the preflight calibrator which offers the advantage of providing calibration signals right up to launch and also the advantage of disturbing the signal path during flight by no more than the normally closed contacts of an unpowered relay.

The preflight calibrator designed by Northeastern University has a capability of calibration up to 20 VCO channels with precision voltage levels of 0.000 volts, 2.500volts and 5.000 volts. The calibrator is controlled and powered through the umbilical cable from the control console in the blockhouse. This renders it incapable of being activated during flight or being left in a calibrate condition during launch. Physically the preflight calibrator is housed in an aluminum box 108 x 67 x 45 mm. and its input and output connectors are the same 25 pin "D" type that are used on the VCO mount. By using the same connectors as the VCO mount and judicious placement of the preflight calibrator, the preflight calibrator can be totally by-passed, if desired, without any wiring changes by connecting the input connector of the preflight calibrator

directly to the input of the VCO mount.

The block diagram for the preflight calibrator is shown in Figure 1 and the schematic diagram is shown in Figure 2 illustrates an 18 VCO application. The logic family used for timing the calibration voltages is C-MOS and the relays are dual-in-plane (DIP) reed relays. A brief description of the circuit operation is as follows: (see Figure 2).

Upon being powered from the blockhouse control box, (28 volts via pin 18) all reed relays are activated and the oscillator, U1 clocks the decoded divide-by-eight counter. These eight outputs are connected in pairs to "OR" gates in U3 and the outputs of U3 drive solid state relays U4 and transistor Q<sub>1</sub> to sequentially select the 0.000, 2.500, and 5.000 volts outputs of the precision voltage regulator U5. The precision outputs are connected to all the normally open contacts of the 9 reed relays used to calibrate 18 VCO channels. The normally closed contacts are connected to the data outputs of the experiments. The outputs of each relay drive the VCO's. These relays are energized at the same time as the power is applied to the calibration producing circuits, thus the VCO's are driven by the data when the preflight calibrator is unpowered and by the calibration voltages when it is powered.

This type of preflight calibrator was successfully used on the flight of a Field Widened Interferometer Payload (31.702) which was launched on 2 Aug, 1979.

#### B. S-Band to P-Band Down Converter

The anticipation of an unusually high number of field support activities expected in early 1979 caused some concern about a possible shortage of S-Band receivers. Accordingly, a feasibility study was undertaken to determine if existing P-Band receivers, with intermediate frequency bandwidth capabilities matching those required by the S-Band receivers, could be used in conjunction with down converters each consisting of a local radio frequency oscillator and a balanced mixer. Although available balanced mixers had a

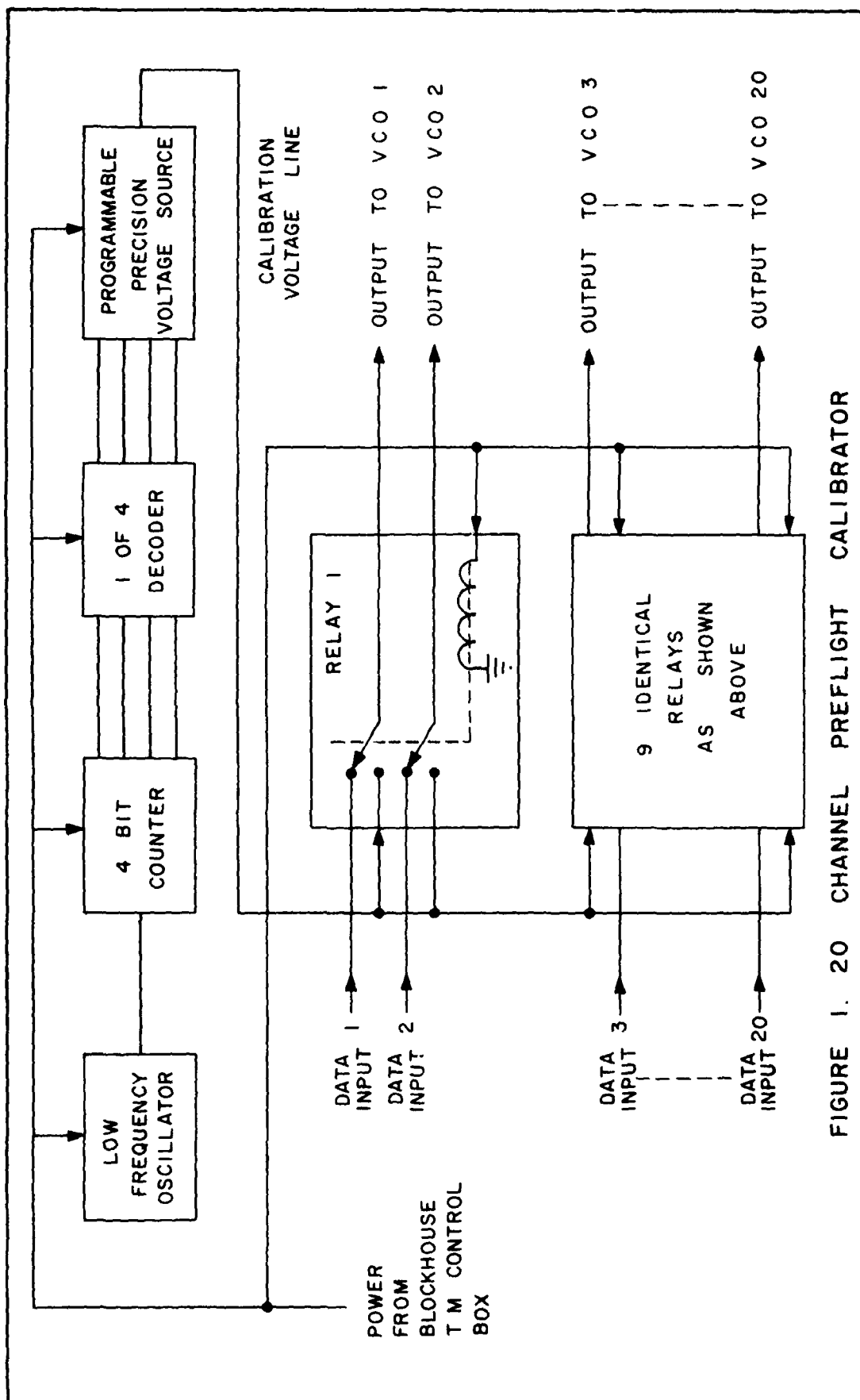


FIGURE 1. 20 CHANNEL PREFLIGHT CALIBRATOR



conversion loss of from 6 to 12 decibels which would degrade the received signal to noise ratio it was felt that this receiving system would be quite suitable for use as ground check out equipment where received signal strength is very high. If necessary, the down converter could be preceded by a low noise preamplifier which would greatly improve the overall receiving system capability.

Tests were conducted to determine the conversion loss of this particular down converter system. Figures 3 and 4 show the configuration and the type of equipment used to make these measurements. The first test used the configuration in Figure 3 to calibrate the signal strength meter of the receiver to that of the output of the signal generator. This calibration also took into account the losses in the interconnecting cable and connectors. The second test consisted of mixing the test signal of 2250 MHz with a local oscillator set at a frequency of 2000 MHz to produce a difference frequency 250 MHz. Signal power in the receiver was recorded and plotted as a function of input power at 2250 MHz. This was done for local oscillator power levels of -10 dBm, 0 dBm, and +5 dBm.

The results of these tests are plotted in Figure 5. The approximate conversion losses for each of the three local oscillator power levels are shown in Table 1 located on Figure 5. The mixer used for this test was a Relcom M2F and it was rated for a local oscillator input of +5 dBm. The specification sheet on this mixer indicated an expected conversion loss of from 6 to 10 dB.

In specifying local oscillator source for actual field operation; a fixed frequency crystal controlled type was initially considered, but due to the fact that the frequency range converted by S-Band receiver (2200-2290 MHz) is twice that of the P-Band receiver (215 to 260 MHz) a variable oscillator is desirable. A local oscillator with a frequency of 1985 MHz will allow tuning S-Band frequencies from 2200 to 2245 MHz into the P-Band range, and a local oscillator with a frequency of 2030 MHz will allow tuning from 2245 to 2290 MHz. A tuned

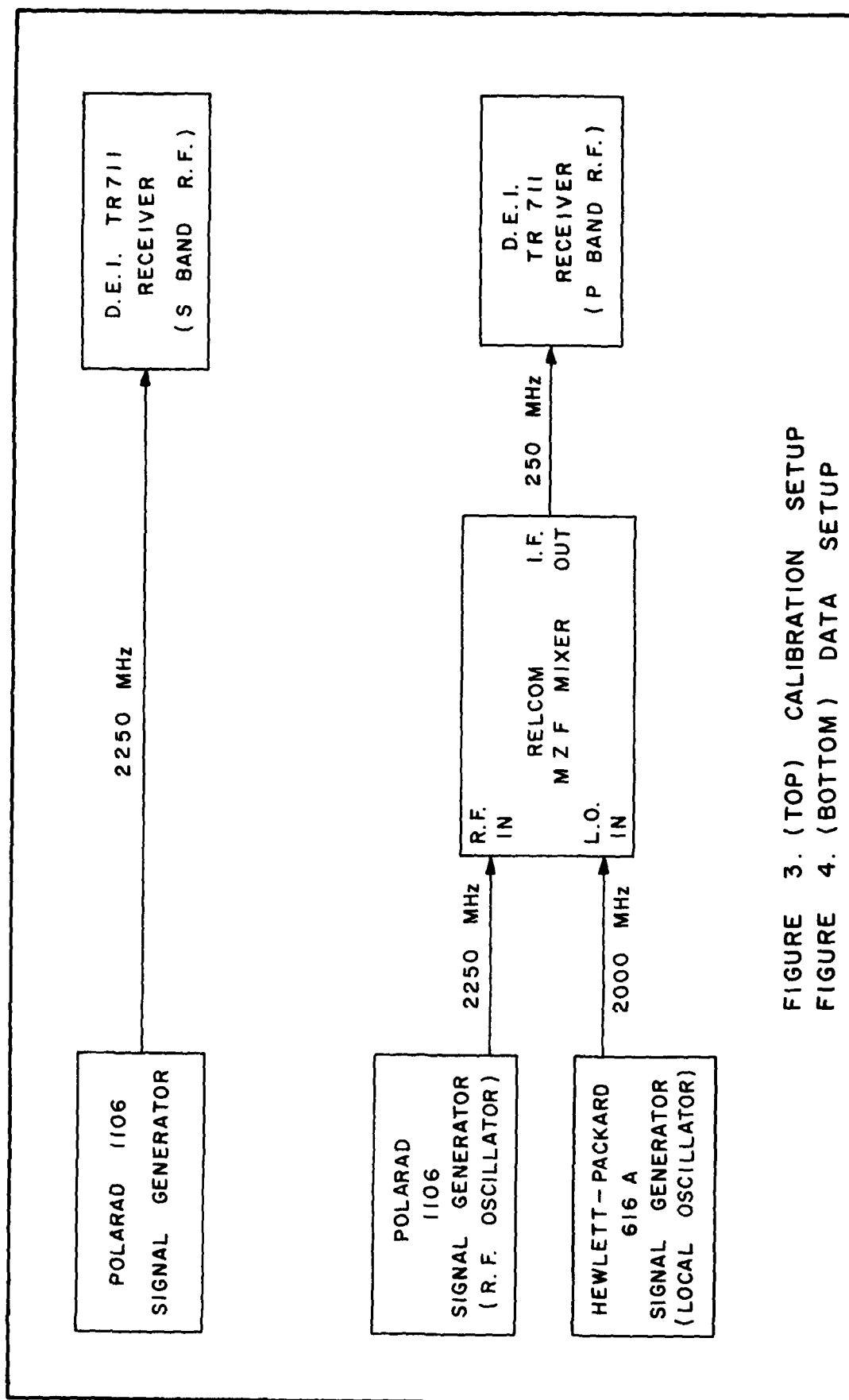


FIGURE 3. (TOP) CALIBRATION SETUP

FIGURE 4. (BOTTOM) DATA SETUP

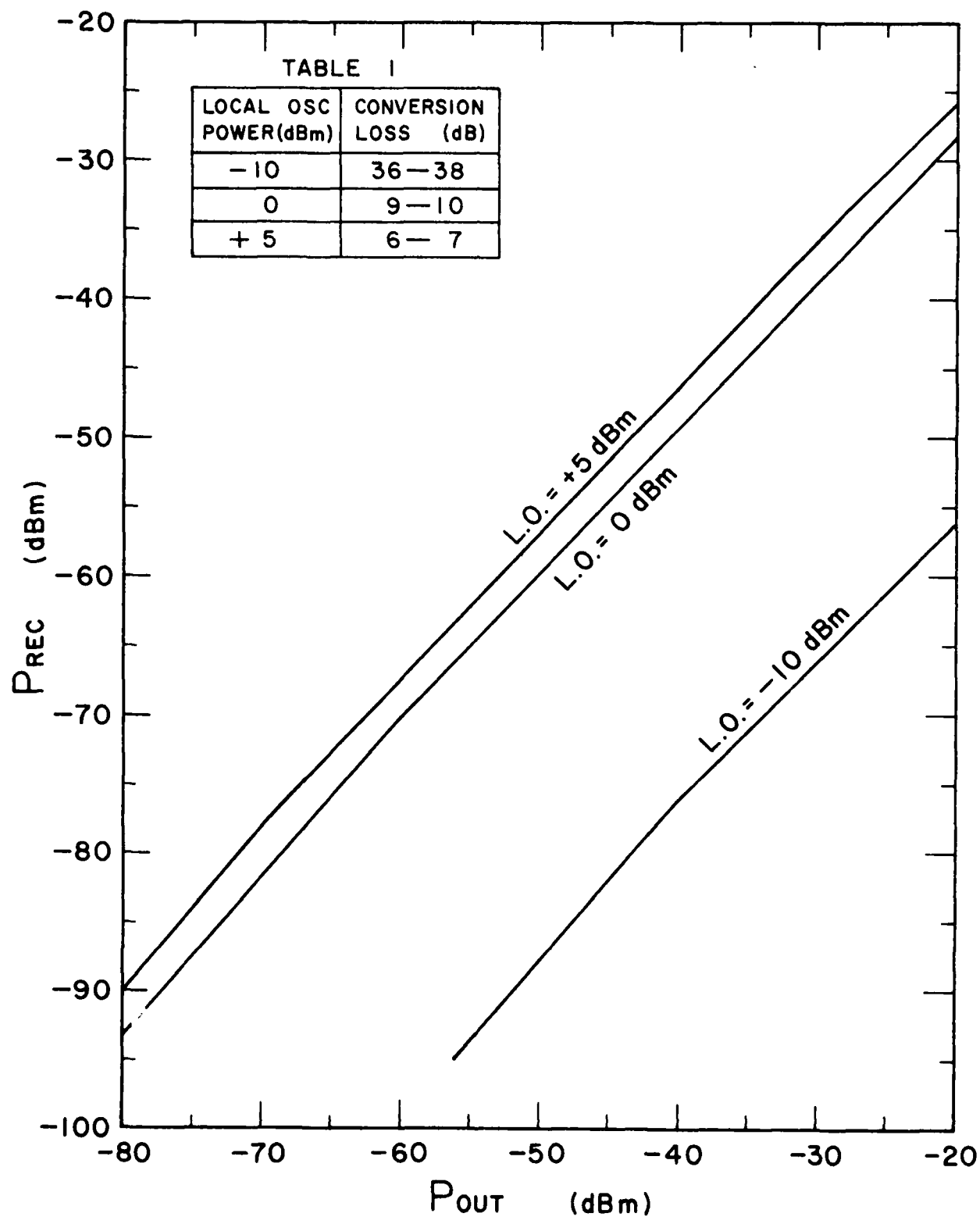


FIGURE 5. CONVERSION LOSS OF A RELCOM  
MZF S BAND MIXER



cavity oscillator converging the range from 1985 to 2030 MHz would allow total S-Band coverage. A voltage controlled oscillator having the same tuning range would also suffice as a local oscillator but would have the advantage of remote dc controlled tuning and preset channel selection capability.

By November, 1978, it became clear that the field activities contemplated for early 1979 would not be as high as had been anticipated so the hardware implementation of this feasibility study described above was phased out.

#### C. Ground-Based Radiometer System

The ground based radiometer system described in the Final Report of the previous contract was developed for deployment in Meppen, W. Germany as part of the basic measurement package of Project OPAQUE. Under this contract, problems involving interfacing the automatic gain control system with the photomultiplier and synchronous locking amplifier were eliminated. Ground loops, noisy cables and a defective solid state cooling system for the detector were found to be the cause of high ambient noise. Once overcome, the equipment was shipped to W. Germany.

The system operated properly when installed in the field with the only failure occurring when the power polarity was inadvertently reversed. The damaged unit was returned to Northeastern University and repaired. This system was operated for over a year at the field site on a 24 hours-a-day basis. The data acquired by this system is still being reduced at AFGL.

Details of this experiment and associated instrumentation are presented in AFGL Technical Memorandum No. 5 entitled "AFGL Day/Night Path Radiance Meter-Project Opaque" by Robert B. Toolin and Norman C. Poirier, dated July, 1977.\*

A gain control system similar to that constructed for the aforementioned project was constructed for another instrument used for optical data gathering

\*Distribution of this document is limited. Request for this document may be addressed to AFGL/LHW, Hanscom AFB, MA 01731.

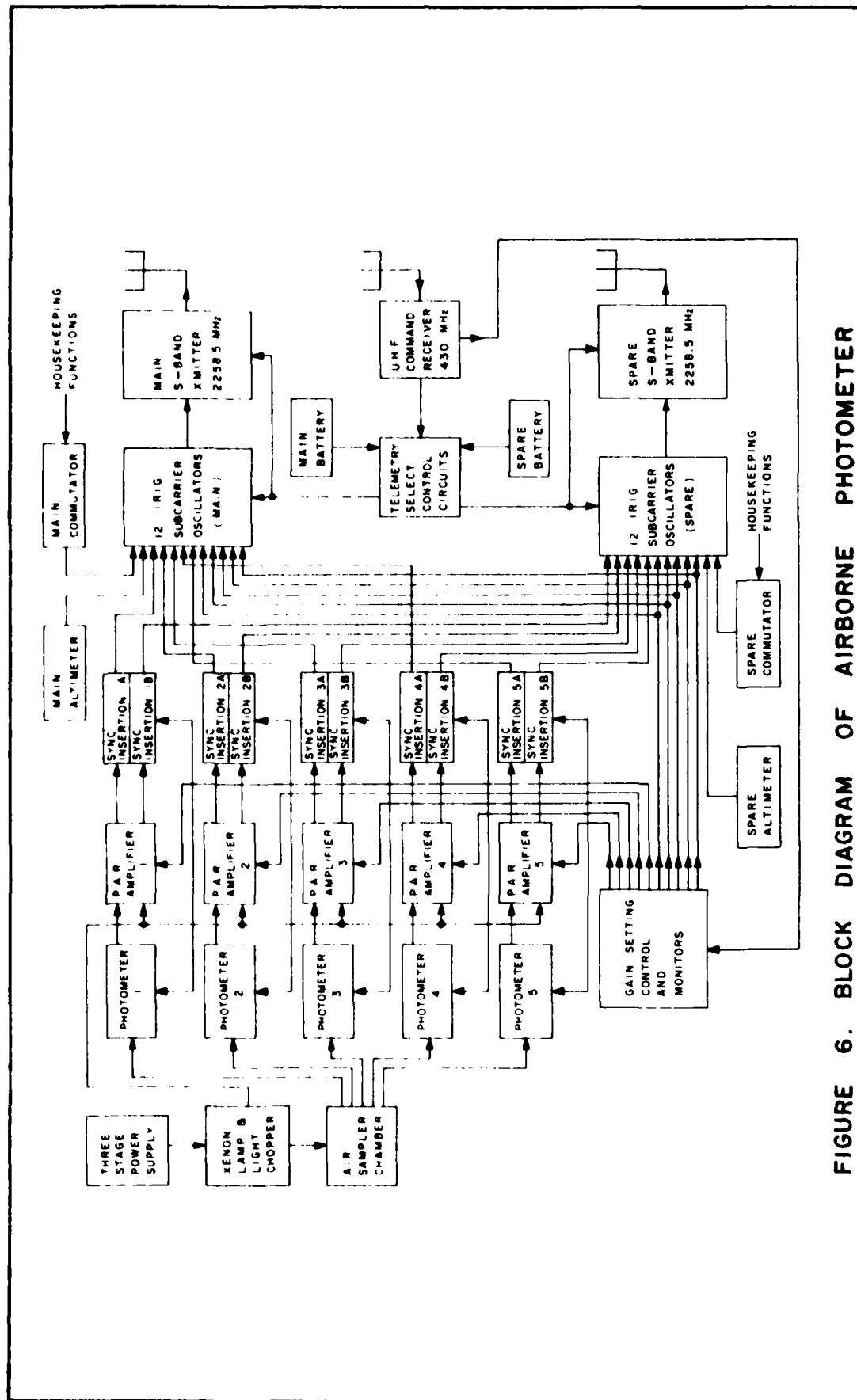
at the same field site in Meppen, W. Germany. This system controlled the gain of a Princeton Applied Research Model 186 synchronous amplifier over a range of 5 decades of voltage gain. This system included an inhibit feature which could interact with the digital recording system such that the gain could not change while data was being processed by the analog-to-digital converter of the PCM encoder.

#### D. Airborne Photometer

In the Final Report of the previous contract, a balloon borne instrument for measuring the scattering of visible light from particulate matter in the upper atmosphere was described. Northeastern University had responsibility for airborne telemetry, pretransmission signal conditioning and data reduction for preflight and post flight calibrations. The block diagram of the airborne unit is shown as Figure 6. The balloon flight of 1974, while meeting experimental objectives, indicated serious problems in several areas. These areas and the steps taken to rectify these problems are listed below.

Lamp Power Supply The power supply used to excite the lamp which illuminates the aerosol particle proved to be very unreliable. During preflight testing and calibration, the lamp would not ignite reliably and would sometimes extinguish during calibration tests. An early failure of this supply terminated the first flight of this instrument in failure. Defective portions of the supply were redesigned and built from locally available components and a second flight in June 1974 was completely successful.

In anticipation of another series of balloon flights of this system, a completely new power supply for the Xenon lamp was designed and constructed. To ignite a Xenon lamp of this type, three different supplies must be sequenced in proper order



First a very high voltage pulse of approximately 30,000 volts must be applied across the two terminals of the lamp. This established a narrow ionization path which allows effective application of a medium voltage source of 350 volts. This enlarges the width of the ionization path, thus lowering the resistance of the lamp to a point where a constant current source of 7.0 amperes will maintain the lamp ignited. The drop across the tube at 7.0 amperes is approximately 21 volts thus giving the tube its 150 watt rating. If the lamp should extinguish for any reason, this sequence must be repeated. Figure 7 shows a schematic drawing of the new power supply.

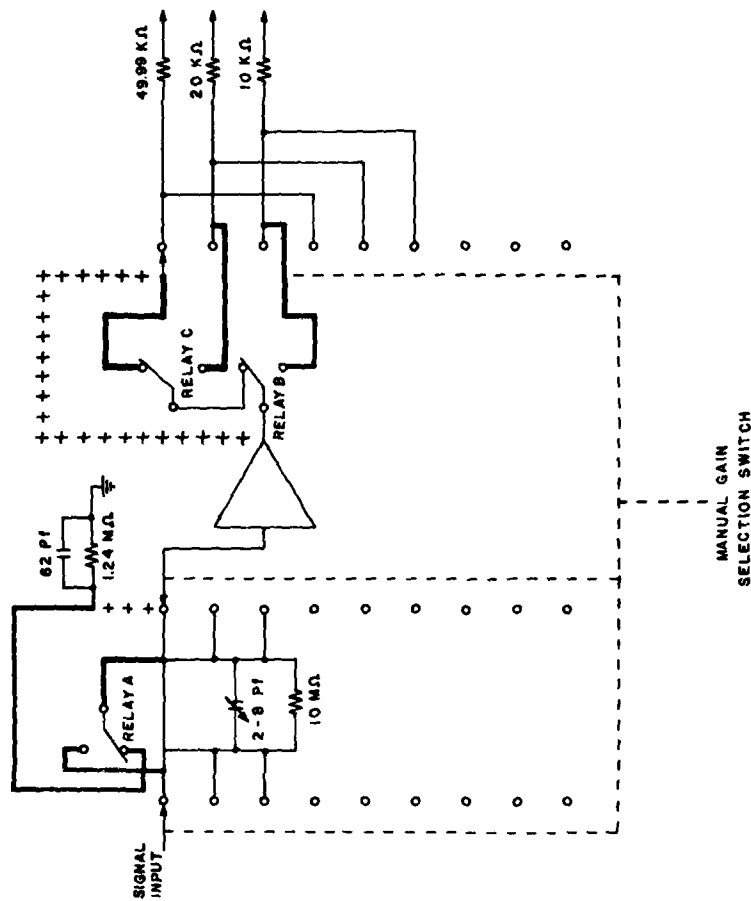
A brief description of the power supply's operation is as follows:

The 30,000 volt pulse is obtained by charging  $C_1$  to 400 volts and discharging it thru the primary of  $T_1$  much like the capacitive discharge ignition system in modern automobiles. The capacitor  $C_1$  is discharged by SCR 1 repetitively by a relaxation oscillator composed of four layer diode  $D_2$  and  $C_3$ ,  $R_2$  and  $R_3$ . This oscillator is inhibited when the lamp ignites. The period of oscillation of this firing circuit is approximately 5 seconds. This time allows capacitor  $C_2$  to recharge to 350 volts if the lamp fails to ignite on the first pulse. The 400 volt and 350 volt supplies are redundantly derived from DC-to-DC converters. These converters are energized by a 28v battery supply through relays  $K_1$  and  $K_2$ . These relays are activated when the lamp current falls below a preset level which could indicate the tube has extinguished. This sensing and control is accomplished with two comparators, two relay drivers, and a  $0.1\Omega$  current sensing resistor  $R_1$ . The constant current is produced by comparing the tube current with a preset level on comparator  $CP_3$ , which will switch the redundantly connected combinations of  $Q_1$ ,  $Q_2$  and  $Q_3$ ,  $Q_4$  on and off through inductor  $L_1$  thus producing a switching



regulator type supply. Constant current regulators are characterized by high efficiencies as the series pass transistors are either in the saturation or cut-off stages.

Remote Range Control Another area of difficulty experienced in the first flights of this system was the setting of the gain of the 5 synchronous detector-amplifiers used to process the outputs of the 5 photometers. It was anticipated that the output of the photometers would drop as the payload increased in altitude due to fewer particles entering the monitoring chamber. To compensate for this a simple shunting resistor was removed from the outputs of each amplifier by a pressure sensitive switch at an altitude of approximately 12 kilometers. This proved to give insufficient control as the dynamic range experienced in the first series of flights in June 1974 resulted in data outputs that were saturated for a portion of the flight or were too low in amplitude to be measured. A system was proposed and adopted which would allow remote control of the gain settings of each amplifier-detector during the flight and make gain corrections to keep his data at proper levels. The modification to each amplifier detectors is shown in Figure 8. This modification allowed the amplifier to operate normally when the remote control input was disconnected. This modification allowed the amplifier to remotely have its gain be effectively changed to sensitivities of 1,2,5,10,20, and 50 millivolts full scale. The relays used in the amplifiers were reed relays designed specifically for low-level switching. These relays were controlled by a matrix of diodes and a stepping switch so that each command would increment the gain first upward then downward in the steps mentioned above. The transmission link for the commands was operating a frequency of 437.5 MHz and used standard IRIG FM/FM multiplexing of command frequency subcarrier oscillators.



RELAYS	FULL SCALE
ENERGIZED	SENSITIVITY
NONE	50 mV
C	20 mV
B	10 mV
A	5 mV
A+C	2 mV
A+B	1 mV

RELAYS ARE E1+SC MOD. D1C05

+++ INDICATES REMOVED CONNECTION

— INDICATES NEW WIRING

FIGURE 8. AMPLIFIER REMOTE GAIN SWITCHING CIRCUIT

Data Reduction Aid Each of the photometers employed has, as part of its construction, a rotating filter wheel which sequentially places various filters and a reference blank in the optical path. The output of each photometer consists of analog levels corresponding to the light intensity passing through each filter thus resulting in a pulse amplitude multiplexed format. To aid in preflight and postflight calibrations an automatic decommutator was designed and constructed during the previous contract. This development allowed calibrations to be taken from a digital voltmeter rather than by reading commutated levels on a strip chart. Calibration time as accordingly reduced from a 4 to 5 hour period to less than 1 hour.

#### E. Airborne Television

The development of an airborne television system was undertaken for the Balloon Atmospheric Mosaic Measurements (BAMM) program. In this program balloon-borne instruments were to be flown to make measurements (infrared, etc) of certain terrain features on the earth from altitudes up to approximately 30.5 kilometers. A stabilized, remotely steerable platform would enable instruments to be pointed toward a specific target. The camera, mounted on the platform, was to be bore sighted to the field of view for the instrument to enable scientists and engineers to confirm the orientation of platform and instruments.

The Cohu Model 5410-007 television camera was selected to meet the BAMM requirements. The following features were also specified:

1. Motorized zoom lens with 30-300mm focal length and f5.6 aperature.
2. Motorized iris.
3. Motorized focus.
4. Standard Vidicon tube.
5. Sharp cutoff optical filter to prevent sun damage.



6. Automatic gain control of 5000:1, and
7. Power requirements of less than 10 watts at 22 to 30 volts.

The specified zoom lens would enable the camera's view angles to be varied from  $28^{\circ} \times 21.2^{\circ}$  to  $2.4^{\circ} \times 1.8^{\circ}$  respectively. At an altitude of about 30.5 km this range would vary from a rectangle approximately 15.2 km by 11.4 km to one with approximate dimensions of 1280.0 m. by 975.4 m.

An FM link at 2215.5 MHz was assigned to carry the video signal from the TV camera and so the communication problem reduced to that associated with the large RF bandwidth needed for TV/FM. This problem was not unlike that which Northeastern was considering for a related contract (F19628-76-C-0152) in which we were to supply a television camera for the Multi Spectral Measurements Program (MSMP) and specify the necessary parameters for an FM down link. Bandwidth together with pre- and post-modulation filtering were seen as the major factors in conserving transmitter power and so a Master of Science Thesis in electrical engineering was undertaken by Willard F. Thorn to address these issues. The thesis was completed in September, 1977 and issued<sup>4</sup> as Scientific Report No. 3 under this contract in July, 1979. The material which follows is extracted or quoted from this report.

The transmission system is shown in Figure 9. Experimental evaluation of the spectrum present in the video output of the camera under a variety of conditions led to the preemphasis and deemphasis filters shown in Figures 10 and 11. It was concluded that "By adding the preemphasis and deemphasis filters to the television transmission system the RF signal level into the receiver can be reduced by as much as 10dB below the level that was required without the filters and still get a useable picture. Reducing the signal strength to the receiver by 10 dB is equivalent to moving the source three times as far

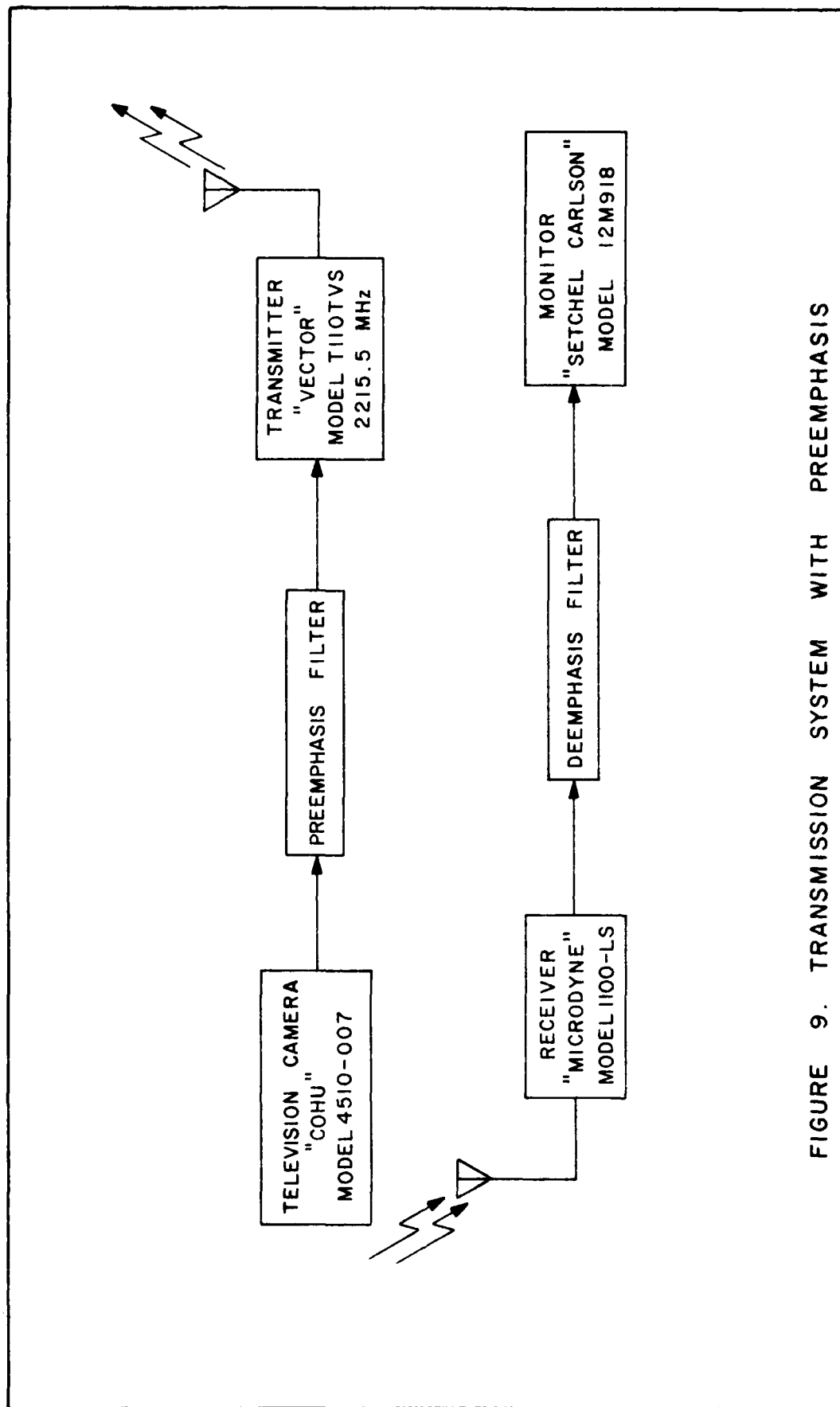


FIGURE 9. TRANSMISSION SYSTEM WITH PREEMPHASIS

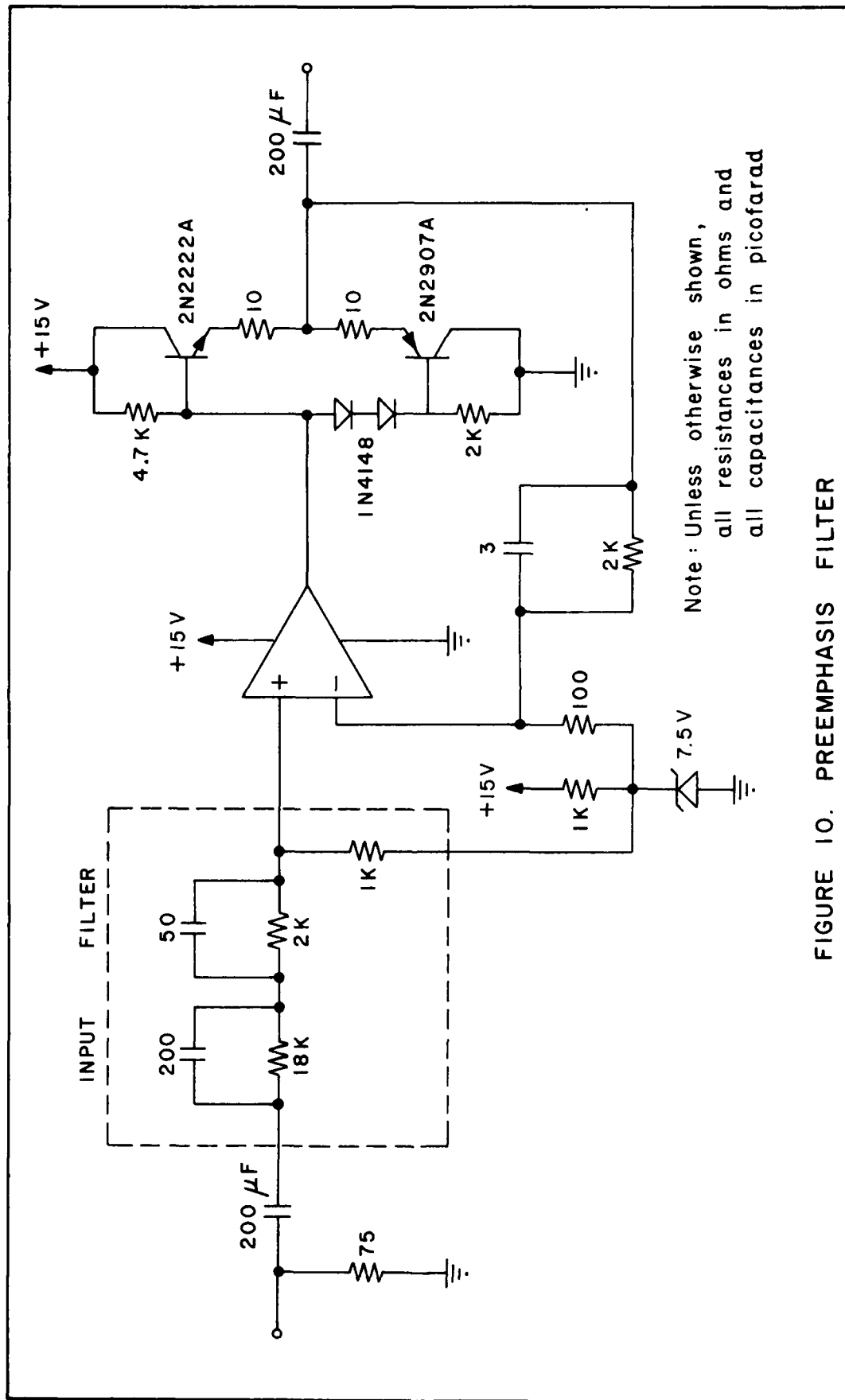
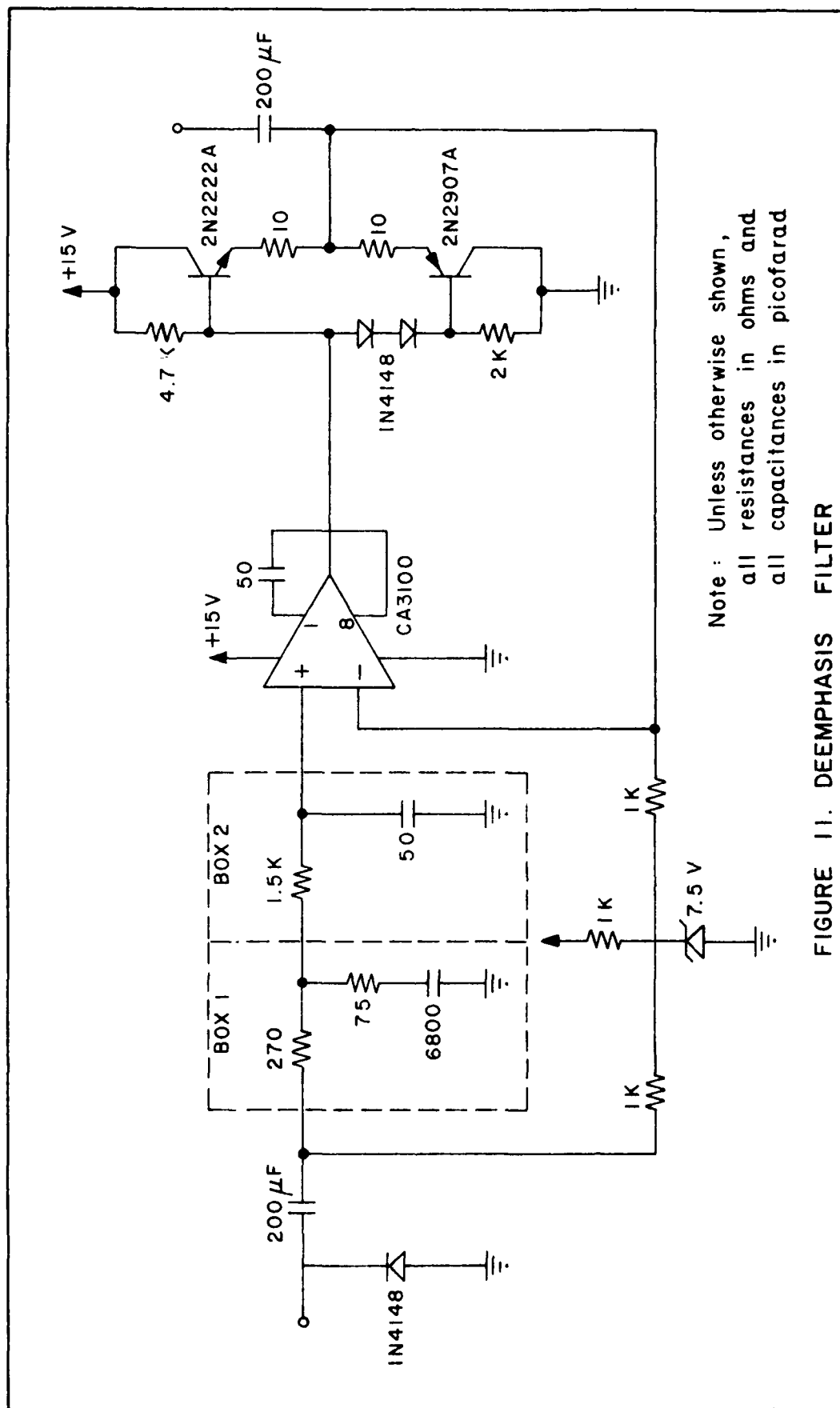


FIGURE 10. PREEMPHASIS FILTER



Note: Unless otherwise shown,  
all resistances in ohms and  
all capacitances in picofarad

FIGURE 11. DEEMPHASIS FILTER

from the receiver. This 10 dB reduction in required signal strength could allow for a 10 dB reduction in transmitted power. In any case, whether one increase distance, decreases transmitter power, or combines these specification changes to the television transmission system, the preemphasis system represents a substantial improvement over the system that uses the video as it comes from the camera to modulate the transmitter.

There is very little more that can be gained by preemphasis than the circuits described here provide when used with the receiver and transmitter used for these tests. The transmission system can operate down to the receiver's threshold with good picture quality. Reaching the threshold results in click noise. The effect of the click noise can be subdued by limiting the maximum signal amplitude with diodes. This only reduces their effect; it cannot eliminate the click. Filtering will only smear out the clicks it will not simply attenuate them."

The television camera system was successfully flown on a number of BAMM flights as is detailed in Chapter II. Sections B and C of this report.

#### F. PCM Encoder

A pulse code modulation (PCM) encoder was designed to accept digital data produced at a non-controlled random rate, asynchronous with the transmission rate. The instrument for which this system was specifically designed is an Echelle spectrometer which has a Reticon 128 element sensor array placed in its focal plane. These light intensity integrating elements are exposed for a period of time which varies according to the previously taken samples in such a manner as to keep the signal levels within 50 to 90% of saturation. At low altitudes, where the atmospheric particle count is high, the exposure time is short. The minimum exposure time has been preset to 67 milliseconds, which corresponds to a maximum sampling rate of 15 per second. At high altitudes the

the sampling rate could be as low as one sample in ten seconds.

At the end of each exposure period the 128 sensing elements, whose individual charge is now proportional to the amount of light which it received, are sent serially at a 32.76 KHz rate to an analog to digital converter and converted to 10 bit words. The output of the analog to digital converter is 128 ten bit parallel words separated in time by 30 microseconds.

At the beginning of each data sampling, the exposure time is encoded into a ten bit word and also, a two bit word is generated to indicate which of four filters was in position during the exposure period of a particular sample. The instrument also generates a "data enable" pulse which occurs just before encoding begins and lasts until the 128th encoding is completed. A "data valid" pulse is also produced which coincides with the analog to digital converter outputting each of the 128 ten bit data words. Figure 12 illustrates the time relationship of these functions.

Figure 13 is a block diagram of the portion of the PCM encoder which accepts the various asynchronous data inputs and forms them into a 1330 bit PCM frame. At the beginning of each sample, at the same time as the "data enable" pulse starts, a narrow pulse,  $T_3$ , is formed which parallel loads the 50 bit parallel to serial converter with the frame sync word, the time of flight from liftoff, the exposure time of this particular sample, the filter position and a complement of the previous "new data flag." The time of flight from liftoff data is generated from a crystal controlled clock which is enabled by the removal of the umbilical cable at liftoff. This time of flight data will be used to correlate the altitude with the spectrometer data. The new data flag will be used to aid in the reduction of the flight data, allowing the computer aided data processor to ignore redundant data. The frame

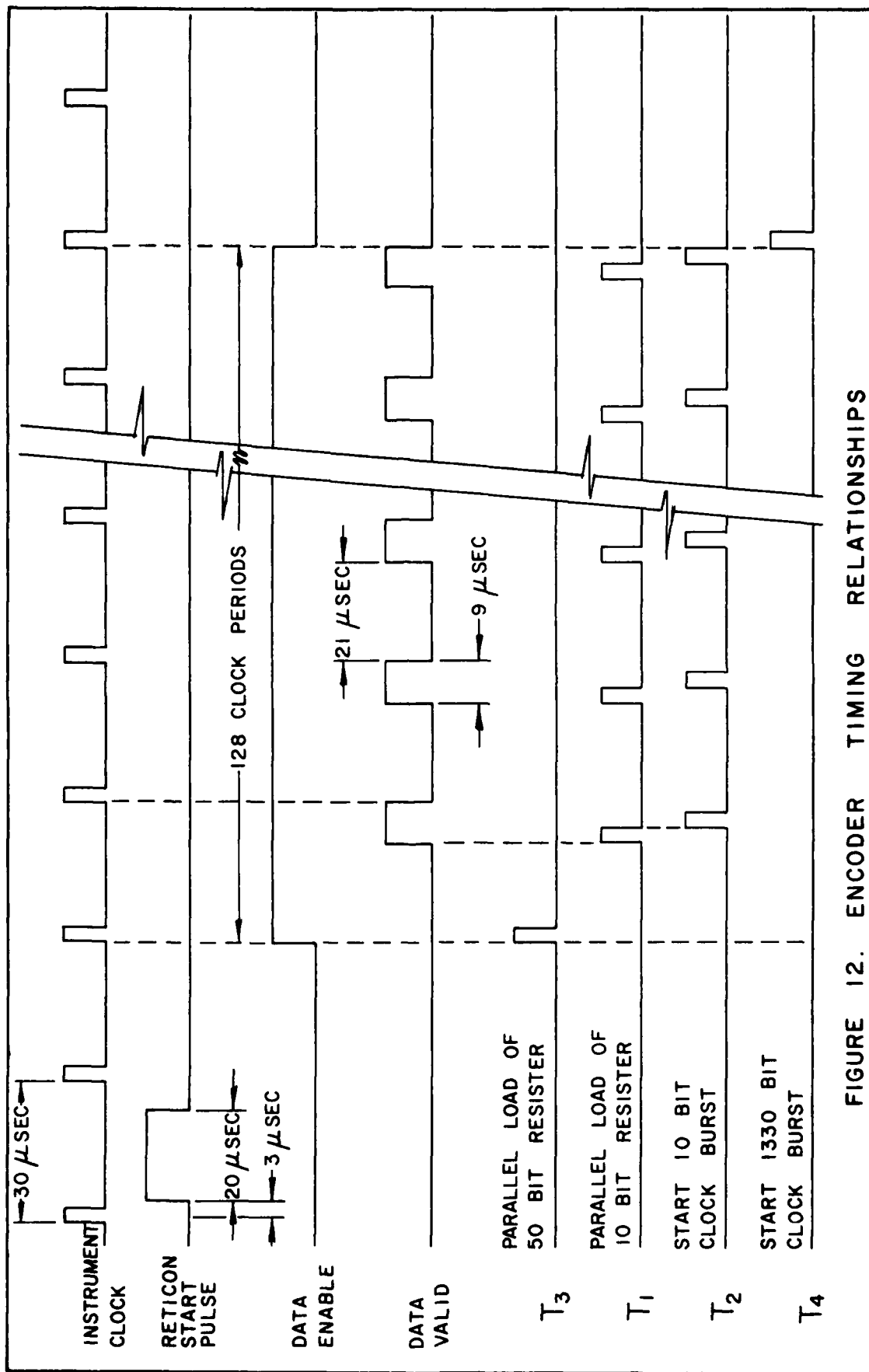
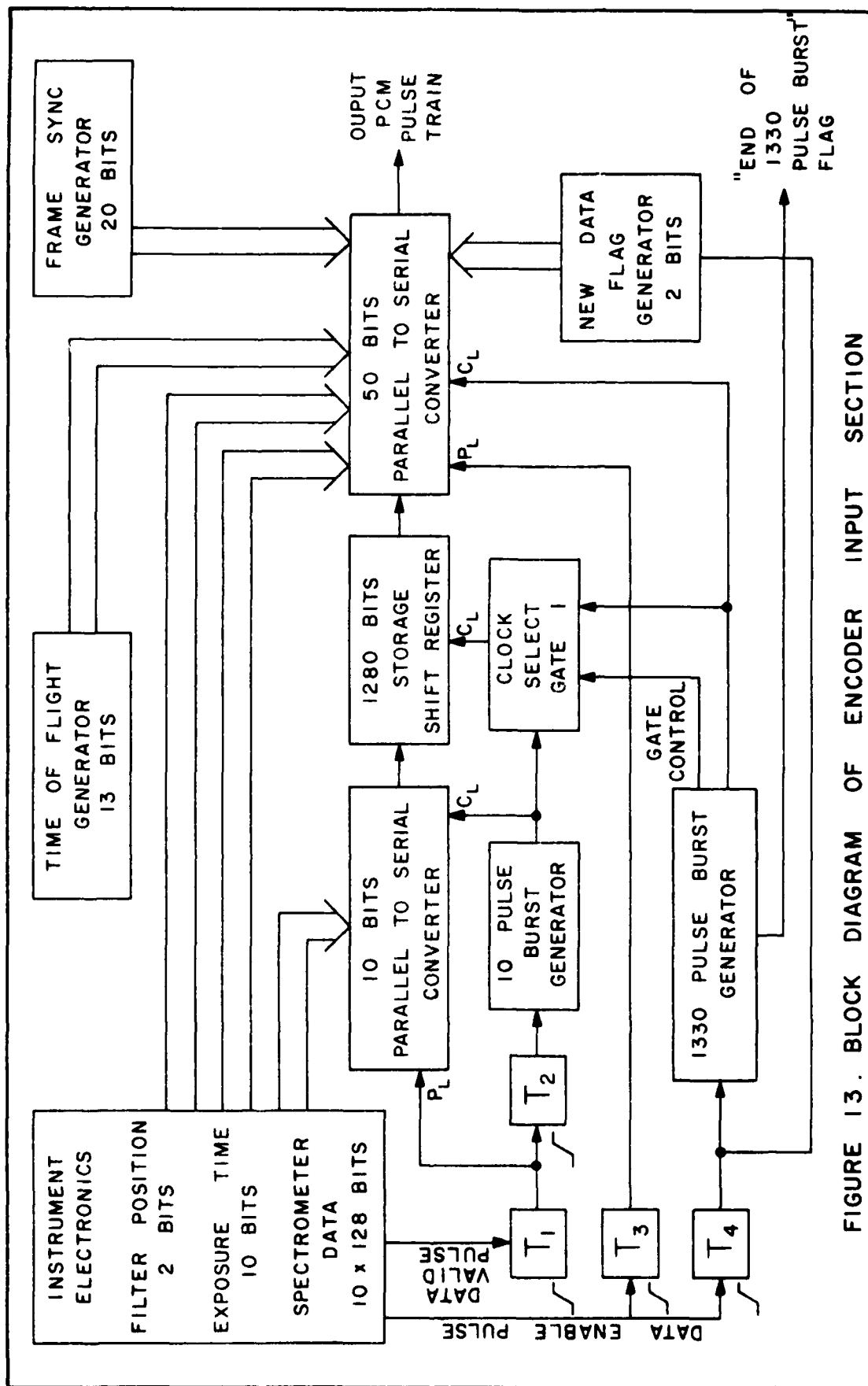


FIGURE 12. ENCODER TIMING RELATIONSHIPS





sync word is a 20 bit code as specified by IRIG, and is hard wired to the parallel inputs of the 50 bit parallel to serial converter.

When the "data valid" pulse begins, a pulse,  $T_1$ , loads the first 10 bit data word into the 10 bit parallel to serial converter then a pulse,  $T_2$ , starts the 10 pulse burst generator which clocks these 10 bits into the 1280 bit storage register. This load and shift sequence continues until all 128 data words are loaded into the 1280 bit storage register. At this time the "data enable" pulse ends and triggers a  $T_4$  pulse which starts the 1330 pulse burst generator and switches the clock select gate 1 to the 1330 pulse burst position. The 1330 pulse burst clocks the 1280 bit storage register and the 50 bit parallel to serial converter to produce an IRIG PCM frame. This pulse train is routed to either output register A or B as shown in Figure 14.

A previously produced PCM frame is circulating in either output register A or B. It is being clocked by  $\phi_3$  through the clock select gate associated with the circulating register (A or B).  $\phi_3$  is the third phase of the four phase clock generator which operates at 25 KHz and is derived from the 100 KHz crystal controlled oscillator.

Data select gate 1 is controlled by the register select logic (RSL) to direct the newly produced PCM frame to the output register which is not circulating the previously produced PCM frame. When the "end of 1330 pulse burst flag" arrives at the RSL, indicating that a new frame is stored in the non circulating output register and the 1330th clock pulse is also received by the RSL, indicating proper synchronization, the RSL reverses the roles of the two output registers allowing the new PCM frame to circulate and enables the other register to receive the next data frame. This switching of role is accomplished by proper selection of the data select and clock select gates by the RSL. The encoder will now output and recirculate this PCM frame until a

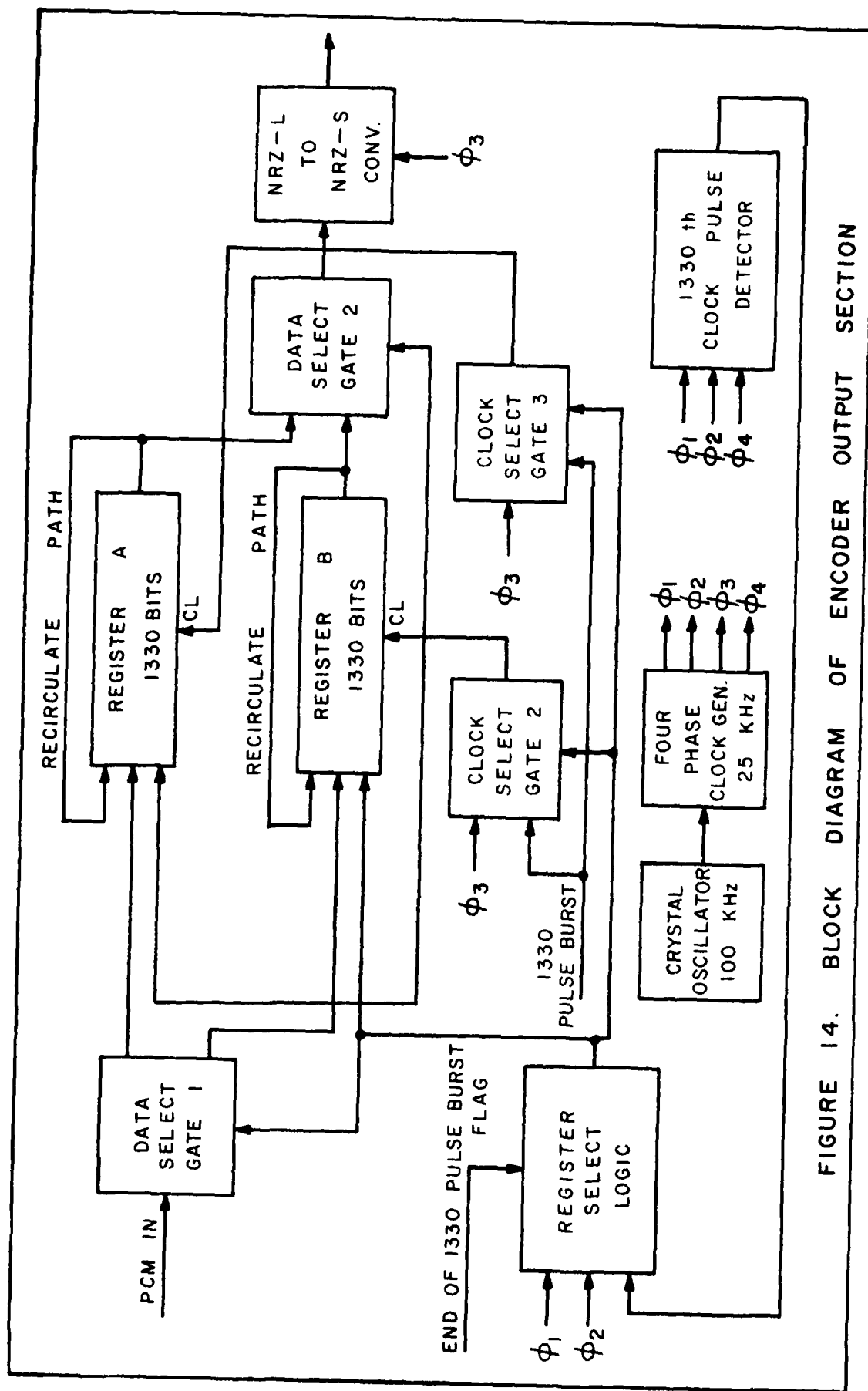


FIGURE 14. BLOCK DIAGRAM OF ENCODER OUTPUT SECTION

newer frame is ready for transmission. The frame rate is 18.8 frames per second.

The output PCM train is generated in a NRZ-L format which is converted to NRZ-S before transmission. This is done to allow sufficient zero-one transitions in the pulse train to allow bit synchronization upon reception by the ground based PCM decommutator.

In order to determine the minimum clock rate of the encoder, it was necessary to calculate the minimum time in which the encoder would be ready to receive a new batch of data after processing the previous sample. Once the data is entered into the non circulating output register, it must wait up to 1330 clock period before it can be outputed. The minimum time between data samples is determined by the maximum sampling rate of 15 per second. This gives a period of 67 milliseconds. The data acquisition time is 3.9 milliseconds and the time required to shift the new data into one of the output registers is .6 milliseconds or a total of 4.5 milliseconds. A total time of one output frame period plus 4.5 milliseconds is thus required before a new sample can be accommodated. To find the minimum output clock rate required solution of the following.

$$4.5(\text{ms}) + \text{output frame period} = 67(\text{ms})$$

$$4.5(\text{ms}) + \frac{1330 (\text{Bits/Frame})}{\text{Output Clock Rate (Bits/Sec)}} = 67(\text{ms})$$

$$\text{Output Clock Rate (min)} = \frac{1330}{62.5} = 21.3 \text{ KHz}$$

A clock rate of 25 KHz was chosen to give a margin of safety. Measurements were made with an input data simulator and a maximum sample rate of just over 17 per second was possible. The theoretical maximum rate at a 25KBits/S is:

$$\begin{aligned} 4.5 + \frac{1330}{25} &= \text{Sampling Period (max)} \\ &= 57.70 \text{ milliseconds} \end{aligned}$$

which corresponds to a maximum sampling rate of 17.33 per second.

The logic family for the entire system, including the spectrometer electronics, is C-MOS. A ten volt supply was chosen due to the 12 volt maximum supply voltage of the type 4731 shift registers.

In the flight configuration, the PCM bit stream will drive an IRIG channel-H subcarrier oscillator whose output is combined with other subcarrier oscillators to drive a S-Band transmitter thus making this a PCM/FM/FM system.

A data simulator was designed to verify proper operation of the encoder. This was necessary as the electronics for the Echelle Spectrometer was being built by H. S. S. Inc. concurrent with the construction of the encoder and was not available for interconnection and testing.

The simulator, shown in Figure 15, was designed to produce the same timing signals normally generated by the Echelle Electronics. Panel mounted switches could simulate data, exposure time and filter positions. The data simulator is connected to the same connector where Echelle Spectrometer Electronics would normally connect. Power for the simulator comes from the encoder thru an unused pin on this connector.

The encoder was tested for operation at a temperature of 70°C for 24 hours. During this time, the encoder was actively operated with the inputs being stimulated by the data simulator described earlier. The encoder output was used to drive a standard PCM decommutator which could detect anomalies in system operation. The system performed properly during the test and the power supply current, which is a good indicator of proper performance, remained at its correct level of 10 MA. for the duration of the test.

The encoder was also given a standard random vibration test at the environmental testing facilities at the Air Force Geophysics Laboratory on 5 Jan 1979: The system was not powered during the test. After this test, the

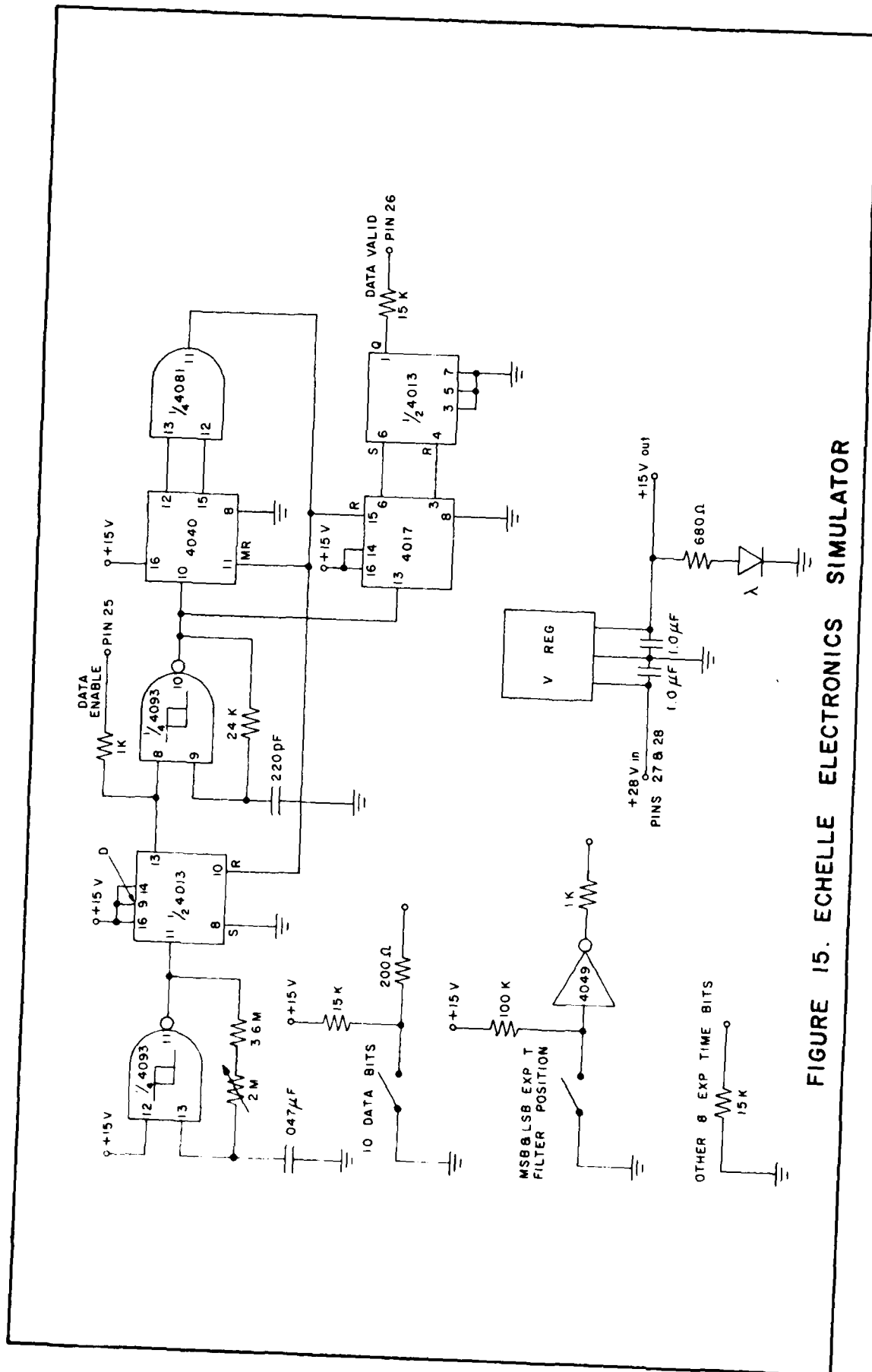


FIGURE 15. ECHELLE ELECTRONICS SIMULATOR

encoder was checked for normal operation. No damage, electrical or mechanical, could be observed.

#### G. Commutated Umbilical Ground Checkout System

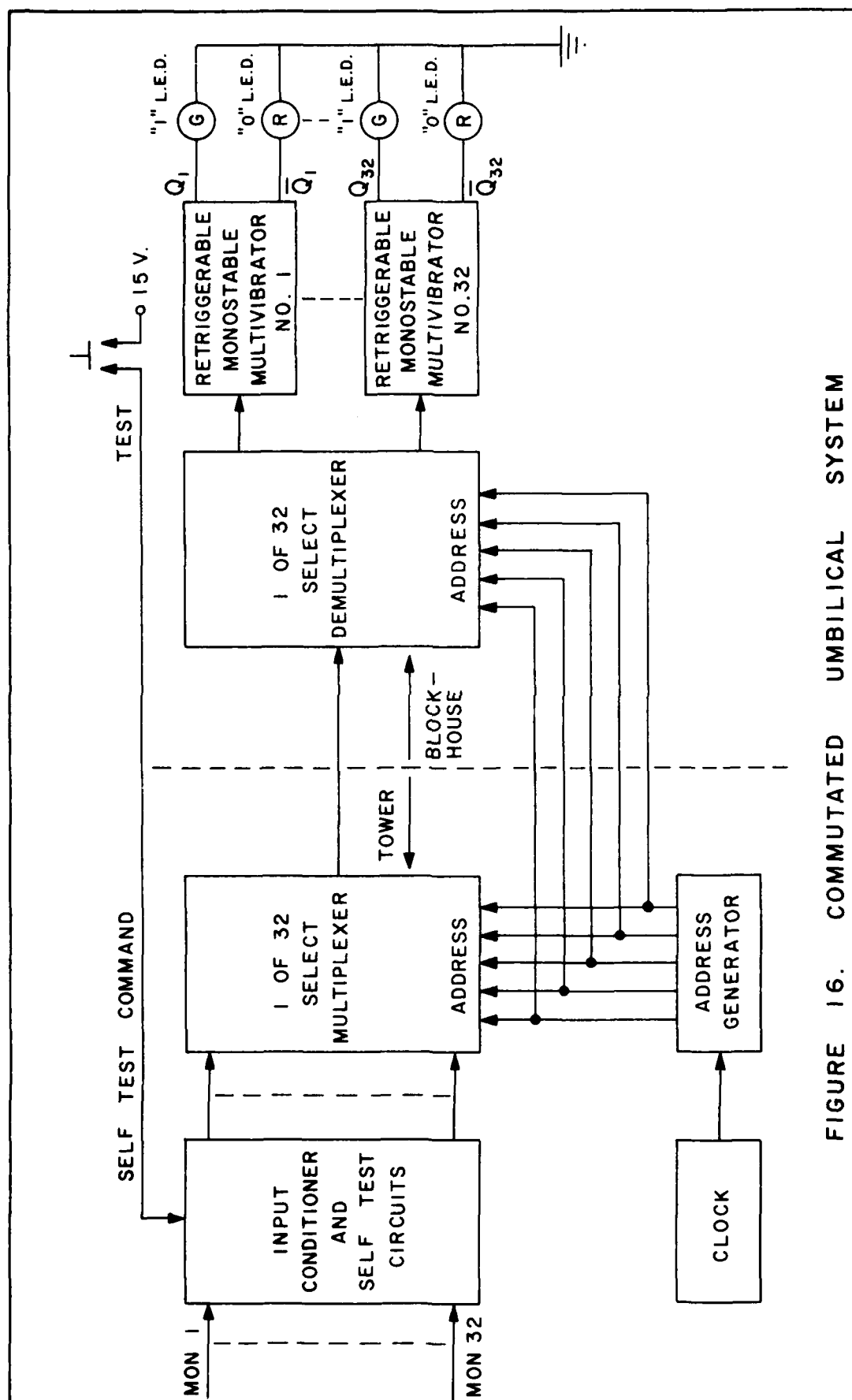
As rocket borne systems become more complex, the demand for lines from the blockhouse to the launch tower has increased beyond the capacity of many existing launch facilities.

These lines are used for various functions including monitors, controls, and power to airborne systems such as scientific instruments, telemetry, attitude control, recovery, and radar transponders.

To optimize the utilization of these lines, a system for time multiplexing many of the monitor functions has been designed. A system was designed for use with vehicle A31.701, a rocket carrying an Echelle Spectrometer as its main instrument. This system can accommodate 32 channels of digital type monitors and uses a total of 7 lines. (This system could be expanded to 64 channels with the addition of one more line.) This system accepts any voltage level from 4.0 volts to 50 volts as a logic "one" level and any voltage from 3.0 volts to zero volts as a logic "zero" level. In Figure 16, the block diagram of this system, it can be seen that same address is applied simultaneously to both the multiplexer and the demultiplexer. This ensures that the system is always in synchronization without the use of synchronization signals and their associated detectors.

Each of the 32 channels on the vehicle are sampled 10 times a second. The demultiplexer in the blockhouse receives the sampled signals, then decodes and drives 32 retriggerable monostable multivibrators. The output for each channel is displayed on the control console as a red light emitting diode (LED) for received "zero" signals and a green LED for received "one" signals.

A self test capability has been included in the system design. If the console operator pushes the test button, a logic "one" is placed on all inputs and



thus all the panel indications should be green. This confirms proper operation of the entire system. Figure 17 shows one of the 32 input stages with the self test circuitry. With the exception of this input stage, the circuitry is all C-MOS integrated circuits. The rocket borne prototype of this system is housed in an aluminum box which measures 7 cm. by 4 cm. by 17 cm., while the control console unit is mounted on a 20 cm. by 12 cm. card.

In this particular application, this system was used to measure the following functions:

- 1) Support power - internal (prime)
- 2) Support power - external (prime)
- 3) Photometer power - internal
- 4) Photometer power - external
- 5) Spectrometer power - internal
- 6) Spectrometer power - external
- 7) Spectrometer calibrator - on
- 8) Beam filament - on
- 9) Beam high voltage - on
- 10) ACS - on
- 11) Squib - armed (prime)
- 12) Squib - safe (prime)
- 13) Atomic oxygen - internal
- 14) Atomic oxygen - external
- 15) Atomic oxygen lamp - on
- 16) Atomic oxygen lamp - off
- 17) Prime timer - run
- 18) Backup timer - run
- 19) Timer - armed (prime)



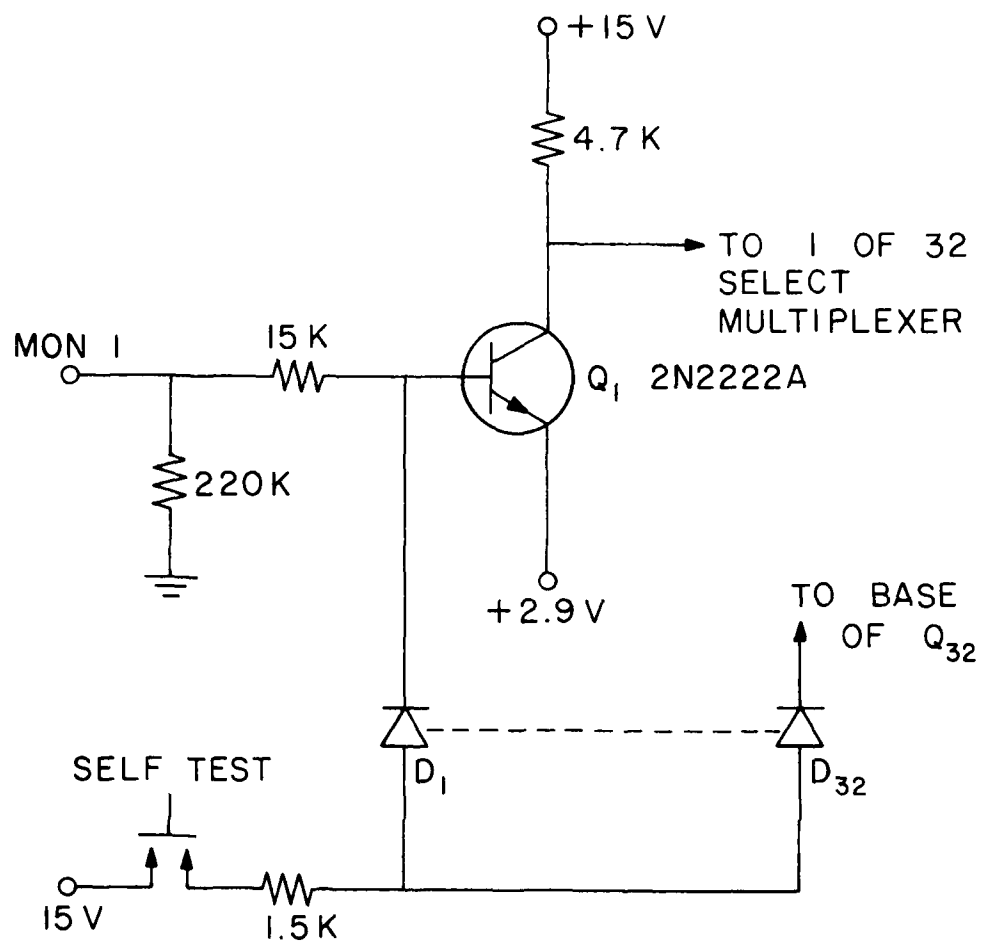


FIGURE 17. INPUT STAGE

- 20) Timer - safe (prime)
- 21) Squibs - armed (backup)
- 22) Squibs - safe (backup)
- 23) Support power - internal (backup)
- 24) Support power - external (backup)
- 25) Timer - armed (backup)
- 26) Timer - safe (backup)
- 27) Initiate data taking - on
- 28) Initiate data taking - off

## CHAPTER II

### AIRBORNE INSTRUMENTATION

#### A. Rocket Systems

During the period of this contract Northeastern University has continued to provide engineering support for rocket systems in the areas of telemetry systems, radar and tracking systems, recovery acquisition aids, attitude determining devices, including gyroscope platforms, and ground based receiving and recording checkout stations for the individual rocket payloads. This support has resulted in thirteen rocket launches. Four other payloads systems were not launched due to improper scientific conditions. The details of this field support is covered in Section C of this chapter.

The specifications of certain subsystems and the resulting designs of circuit developments described in Chapter II of this report were usually a direct result of requirements set forth in these rocket systems.

The following sections describe the rocket systems completed during this contract.

1. HIRIS (IC 630.02-1A). The HIRIS payload consisting of a High Resolution Interferometer Spectrometer designed at the Honeywell Radiation Center was assigned to Northeastern University under a previous contract, F19628-73-C-0148 and in conjunction with "Northeastern contract F19628-73-C-0152". The vehicle telemetry consisted of two S-Band links, one of PCM/FM for instrument data and the second of FM/FM, including 15 subcarrier oscillators for housekeeping and service module data. The tracking was accomplished by use of an S-Band radar transponder and the DNA ranging system. Recovery was aided by the use of a tone modulated beacon at 242MHz.

Further instrumentation included an inflight calibrator, a first motion switch, and a new design of a flight programmer. These subsystems were described in the Final Report of the previous contract.

The HIRIS vehicle was launched via a Sergeant motor on March 31, 1976 into an auroral arc. All systems performed well except that the payload went into a tumble mode resulting in the instrument looking at earth limb during phases of its flight. The recovery was accomplished with all systems operational and no visible damage to the payload.

2. Multi-E-Field (IC819.08-1).

The experiments on this payload were supplied by Utah State University and consisted of an E-field, HARP, Plasma frequency, Capacitance, and DC probes, Electro-Static Analyzers, Photometers and Electron Deposition Scintillators. The data from these instruments was transmitted to the ground receiving station by way of three FM/FM telemetry links. Two of these links utilize Vector T105S five watt transmitters at 2251.5 MHz and 2279.5 MHz and are multicoupled onto one stripline antenna on the vehicle body. The third link at 2241.5 MHz is contained in an ejectable nose cone with Electron Deposition Scintillators. The three data links were of the FM/FM type and consisted of fifteen, twelve and seven subcarrier oscillators respectively.

The mechanical fabrication and support systems were handled in conjunction with Northeastern effort on Contract F19628-76-C-0152.

Tracking and trajectory data were recorded at the appropriate range station through the use of an S-Band radar transponder and the DNA tone ranging system.

After a previous attempt at the Poker Flat Research Range, Alaska during November 1977, the experiment was successfully launched on a Sergeant Hydac vehicle on February 27, 1978. The payload attained a peak altitude of 430 km and all experiments, support systems, telemetry and tracking performed well. The signal levels from the two main body telemetry links seemed low yielding occasional dropouts. This was attributed to an attenuation problem in the multicoupler during flight.

### 3. LN<sub>2</sub> Interferometer (A04.602).

This payload was in support of a liquid nitrogen cooled Interferometer experiment as provided by the Steward Radiation Laboratory of Utah State University. The mechanical fabrication and support systems were handled in conjunction with Northeastern's effort of Contract F19628-76-C-0152.

Tracking and trajectory data were recorded at the appropriate range station through the use of a C-Band radar transponder.

The telemetry data was transmitted to the ground receiving stations by way of two links, a PCM/FM link of 320 kb/s NRZL at 2251.5 MHz and an FM/FM link at 2279.5 MHz that consisted of 9 subcarrier oscillators.

The rocket was launched successfully from the WSMR in New Mexico via an Aerobee 170 vehicle on December 12, 1977. Recovery was successfully accomplished after impact.

### 4. Composition Technology Experiment (A10.705-1).

This payload in support of a Mass Spectrometer experiment was built at Northeastern University under Contract F19628-76-C-0152 in conjunction with telemetry and tracking systems from Oklahoma State University. Northeastern University was assigned the field services for the telemetry and tracking system under this contract. The experiment was launched on a Paiute-Tomahawk vehicle on September 24, 1977 from the White Sands Missile Range, New Mexico.

Tracking and trajectory data was recorded at the appropriate range station through the use of a C-Band radar transponder.

The telemetry data was transmitted to the ground receiving stations via an S-Band FM/FM link consisting of 19 subcarrier oscillators. All telemetry and tracking functions performed successfully as expected and recovery was accomplished.

##### 5. Dynamics Payloads (IC807.15-1,2)

These two payloads consist of dual channel radiometer instruments on Nike Hydac vehicles. The program consists of near-simultaneous launches of these payloads over and under the same auroral arc and closely followed by a chemical release payload on a Nike-Javelin.

Both payloads are identical in experiment and support systems, except one has a telemetry frequency of 2251.5 MHz and the second has a telemetry frequency of 2279.5 MHz. There are thirteen subcarrier oscillator channels on each.

Both of these payloads are to be recovered, so that both have been supplied with the ADF system at 242.0 MHz operated by a lithium battery pack.

Both payloads have been equipped with Tone Range receivers and S-Band radar transponders for vehicle tracking purposes.

The program was prepared for launch at the Poker Flat Research Range, Alaska during the February/March window in 1978. Due to the fact that proper scientific conditions were never attained the program was rescheduled for the October/November 1978 window and the payloads stored at the launch site. An additional payload operated by Utah State University under DNA funding was incorporated into the fall program.

On October 26, 1978 IC807.15-1 was launched. This was followed by an attempt to launch IC807.15-2 at T+2 minutes 40 seconds but no lift off occurred because the launch of IC807.15-1 damaged the ignitor lines on IC807.15-2. At T+3 minutes 50 seconds the chemical payload was launched, a second stage ignition failure occurred in that launch. The fourth payload, the USU Energetics payload was successfully launched at T+12 minutes 30 seconds.

Payload IC807.15-1 was successful and recovered at a later date. The second radiometer payload IC807.15-2 was recycled for a subsequent launch. The proper

auroral conditions were not attained so that the payload was removed from the launcher after its 50th night upon count. The Dynamics payload were first counted in an Auroral program on February 24, 1976 under a previous contract.

6. Field Widened Interferometer, (IC830.09-1A).

This payload was flown at the PFRR during the field trip conducted in the October/November 1977 period. The telemetry, tracking and recovery aspects of this dual link payload were handled directly by AFGL personnel. Subsequent launches of the payload were with the telemetry, tracking, and recovery systems being handled by Northeastern University personnel. The launch of the FWIF payload (IC830.09-1A) was accomplished on November 12, 1978 into an auroral arc breakup. Support systems and telemetry all performed well during flight and a successful recovery was accomplished two days later.

The FWIF program continued with a subsequent launch at WSMR, New Mexico on August 2, 1979. This payload, designated A31.702, was launched via an Astrobee-F vehicle successfully and recovered. Northeastern University was responsible for a dual link telemetry system at 2251.5 MHz and 2279.5 MHz multicoupled onto a stripline antenna. The system was similar to that previously launched at PFRR and consisted of a PCM/FM link of a non-standard NRZ signal at 420 Kbps. Link 2 was an FM/FM system consisting of seven subcarrier oscillators.

Northeastern also had the responsibility for pre-launch and launch operation of the C-Band radar transponder and the Midas Gyro Platform.

It should be noted that when an ACS system replaces the Midas Gyro Platform at PFRR the number of subcarriers on link 2 increases to sixteen.

7. Eclipse '79 Program.

Northeastern personnel handled the telemetry and tracking section for a tri-channel radiometer experiment that was successfully launched on Nike Orion (A12.9A2) into the totality of the eclipse on February 26, 1979. This payload was last flown during ICE CAP 75 at PFRR, Alaska.<sup>4</sup> The telemetry system

frequency is at 2221.5 MHz and is modulated by eighteen subcarrier oscillators. Payload tracking was accomplished by using the Oklahoma State University tracking and ranging system.

Northeastern also handled the responsibility for providing and servicing the recovery beacons on the Mass Spectrometer payloads A10.802-1,2. Each system consisted of a Conic Beacon at 242 MHz with its associated antennas and lithium battery packs.

The Northeastern University involvement consisted of a field party of seven people, three of which were assigned to the subject contract, who left for the Red Lake, Ontario launch site on February 8, 1979. The responsibilities of this team consisted of the airborne telemetry and tracking on payload A12.9A2, and the recovery aids on payloads A10.802-1,2. Further assistance was supplied by the ground checkout station in the blockhouse for pre-launch and launch of the above mentioned payloads and for the remaining two AFGL payloads A12.9A1 and A07.712-2.

All payloads were launched during the eclipse on the predicted schedule and preformed well as expected. The mission was considered successful. Both A10.802-1,2 payloads were subsequently recovered.

#### 8. Post Burn-out Thrust Experiment (A18.805).

The experiment comprised of the separation of a payload from a spent motor and observation and measurements of the relative motions of the two bodies. Also, under investigation was the low level post burn-out thrust, outgassing and particulate contamination by spent solid propellant rocket motors. The Northeastern telemetry groups involvement basically was associated with a single link FM/FM telemetry system contained on the motor section of the vehicle with ten subcarrier oscillators.

The launch of this vehicle was successfully accomplished on August 7, 1979 at the WSMR, New Mexico.



The mechanical fabrication and electronic support systems were handled by Northeastern on Contract F19628-76-C-0152 and the forward payload telemetry system was supported by personnel from Oklahoma State University.

9. Echelle Spectrometer (A31.701).

This payload was assigned to Northeastern University to be flown in support of the Echelle Spectrometer experiment at WSMR, New Mexico. The telemetry system is a PCM/FM system consisting of an adaptive encoder, previously discussed in Chapter I of this report, fourteen subcarrier oscillators and a five watt transmitter at 2279.5 MHz. The system also contains a C-Band radar transponder for tracking.

Northeastern also took on the additional responsibility for certain electronic support systems. This effort enabled Northeastern to:

- a.) Provide flight timers, squib firing circuits, and relays to properly time and sequence the inflight functions of the Attitude Control System, Payload-Rocket separation, rocket despin, nose cone ejection, instrument door ejection, and various on and off control of scientific instruments. All of these functions will be redundantly controlled by a back up system.
- b.) Provide engineering data gathering devices to measure acceleration, temperature, pressure, and magnetic field strength.
- c.) Monitor battery voltages and currents, monitor timer operation, and verify the results of timer controlled functions.
- d.) Provide two commutators, one for monitoring various functions for the experiments and the other for housekeeping parameters.
- e.) Provide a ground console for charging and monitoring the six flight batteries, and
- f.) Provide a ground control console for remotely controlling the experiments, flight timers, and other instrumentation in pre-flight checks as well as during countdown activities.

## B. Balloon Systems

Northeastern's involvement with balloon experiments has, more often than not, included the development of needed instrumentation for the experiment itself, signal conditioning circuits, the telemetry system and control functions responding to ground-to-air radio commands. Many of the development programs described in Chapter I were carried out as a result of the needs of balloon-borne experimenters. Altogether Northeastern was involved in ten launches during this contract period. These field efforts are described in the remainder of this section. The tabulation of field support is covered in Section C.

### 1. Airborne Photometer (Gibson)

The work on balloon borne experiments for measuring the scattering of visible light from particulate matter in the upper atmosphere were carried over from the previous contract. The development of a modified payload was described in Chapter I, Section D.

Two flights of this payload were scheduled for September 1976. The first flight occurred on 8 September and although the xenon lamp failed after 5 hours of flight, most of the flight objectives were met. Post flight calibrations could not be made due to the defective lamp.

A new lamp was installed and calibrated for the next flight which took place on 14 September. At approximately 2.5 hours into the flight, the received telemetry signal strength fell to a point where signal dropouts became excessive. As the balloon should have been well within range for good reception, a transmitter failure was suspected. A command was given to turn off the main telemetry system and then to turn on a totally redundant spare system. This restored proper signal levels and data was received properly for the duration of the 8 hour flight. During the flight the gains of the photometers were changed many times successfully.

After post flight calibrations were completed, an investigation of the low power level from main transmitter was instituted. The failure was found to be caused by a short center pin of a commercially made OSM connector and cable. The failure probably occurred when low ambient temperatures colder than  $-60^{\circ}\text{C}$  caused further retraction of the pin.

The data from this flight was reduced and analyzed at AFGL. The results were presented in a paper delivered at the 10th AFGL Scientific Balloon Symposium by F. Gibson and N. Poirier.<sup>3</sup>

## 2. BAMM Balloon

Northeastern's association with the Balloon Atmospheric Mosaic Measurements, BAMM program commenced at the start of this contract and has continued throughout its duration. Our involvement has resulted in the development of the airborne television camera, the airborne pre-modulation filter, transmitter selection, design and construction of S-Band antenna for TV, de-emphasis filter for ground receiver, airborne UHF antenna for reception of ground commands for TV camera and associated command circuitry.

The airborne TV system is discussed in Chapter I, part E and in reference number 4. The antennas provided were similar to those which have been developed by Northeastern for other balloon applications on this and the prior contract.<sup>1</sup>

Three S-Band antennae comprised of a 6-inch round aluminum ground plane and a  $1/4$  wave stub for the 2215.5 MHz television link were supplied for the test flight at Chico AFB, California in October, 1977. In addition, spike antennas were provided at 423.6 MHz for use in receiving instrument commands.

The development of the airborne television and associated command system was completed with the successful operation achieved in two flights with dummy

payloads at Chico in October, 1979. Since that time our involvement with the program has been associated with occasional instrument repair and the provision of one technician at all operational BMM flights. Northeastern S-Band and UHF antennae are sufficiently broad band that they have been fabricated by AFGL personnel and flown on all BMM flights for all antenna functions: television, PCM data links, FM/FM data links, ranging systems, instrument command, balloon command and command verification. A typical flight has carried about 3 S-Band antennae and 3 or 4 UHF antennae.

### 3. Extreme Ultra Violet Experiment (EUV)

In the final report of the previous contract, the telemetry system configuration and the instrument command system are presented in detail. System integration was performed at Ball Brothers Research Corporation in Boulder, Colorado during the period of 22 to 24 Sept 1976. All mechanical and electrical interfaces were checked as well as any possible interference between the many transmitters, receivers, and instrumentation. The field party arrived at Holloman A.F.B., New Mexico on 12 Oct 76. All preflight checks were made on the airborne systems as well as the ground station. The balloon was launched on 20 October 1976. All communication and control functions operated properly for the duration of the flight, but a failure in the solar pointer, caused by a broken wire at a connector, prevented meaningful data from being acquired.

The second flight of this system was made on 21 April 77. The flight was an unqualified success. An altitude of 41 kilometers was achieved using an 11 million cubic foot balloon. A sounding rocket carrying a similar instrument was also successfully launched from White Sands Missile Range during the balloon flight to gain supporting data. The second flight configuration was similar to that of the first flight with the following exceptions:

1.) The instrument command system was changed from a slow responding HF system to an immediate responding UHF system. This new system was incorporated into the telemetry system and the receiving antenna was built by Northeastern University. The commands include 5 instrument mode controls, on/off commands for the beacon, and a telemetry mode sequencing command.

2.) The C-Band transponder, which is normally supplied to users by the beacon section of White Sands Missile Range in a 20 kilogram self contained insulated package was instead installed separately in the telemetry system package using existing batteries and insulation thereby adding only 1 kilogram to the payload weight. This weight saving allows the experimenter to achieve higher altitudes which is desirable for his particular measurements.

3.) A data communication link was established between the range receiving station, J-10, and the balloon branch facility at building 850 which allows the experimenter to observe data and make command decisions long after the airborne system is out of radio contact with the ground station at building 850. (The J-10 facility has higher location and higher gain antenna which allows it to track the payload to much further distances.)

The third flight of this instrument was made on 19 April 78. It was a completely successful flight which lasted 10 hours. This flight used basically the same system and support as the previous flight with the addition of extra UHF commands to turn the instrument off and on and the use of larger heat sinks on the S-Band transmitters, which had heated to nearly 80°C on the previous flight. The temperature of the transmitter peaked at 70°C during this third flight.

An attempt for a fourth flight was made in September of 1978. Similar flight systems and ground support were used as in the previous flight. The first attempt on 27 September 78 was aborted due to a large number of holes and

tears in the balloon. Using a back-up balloon, another attempt was made on 30 September 78. The balloon was successfully launched but for reasons yet undetermined, a command to terminate the mission was received after only four minutes of flight, which separated the payload from the balloon. The payload was recovered undamaged.

### C. Field Support

This section contains a tabulation of those instances in which field programs required Northeastern University personnel to provide professional and technician level support at field locations. In most instances the travel indicated was to launch ranges to install and operate airborne equipment or provide ground support. In some instances travel was involved with facility evaluation, conferences, or meetings. In any event whenever overnight travel was undertaken the trip was classified as field support and is consequently listed.

<u>Purpose or Launch Date</u>	<u>Location</u>	<u>Vehicle Type &amp; Designation</u>	<u>Trip Duration</u>	<u>Staff</u>
31 March 76	Poker Flat	IC630.02-1A	9 Feb 76 to	Chase
	Research Range, Alaska	HIRIS (Sergeant)	4 Mar 76	
			9 Feb 76 to 18 Mar 76	Marks
			9 Feb 76 to 20 Mar 76	O'Connor
			24 Mar 76 to 2 Apr 76	Chase
8 Sep 76	Holloman A.F.B.	Balloon (Gibson)	1 Sep 76 to	Poirier
14 Sep 76	New Mexico	Balloon (Gibson)	16 Sep 76	Thorn
Interference Checkout	Ball Brothers Res. Corp. Boulder, Colo.	Balloon (Hall)	22 Sep 76 to 24 Sep 76	Poirier
20 Oct 76	Holloman A.F.B.	Balloon (Hall)	12 Oct 76 to 22 Oct 76	Poirier
	New Mexico			

<u>Purpose or Launch Date</u>	<u>Location</u>	<u>Vehicle Type &amp; Designation</u>	<u>Trip Duration</u>	<u>Staff</u>
Balloon Symposium (AFGL)	Portsmouth, NH		21 Oct 76 to 22 Oct 76	Rocheport
21 Apr 77	Holloman AFB New Mexico	Balloon (Hall)	11 Apr 77 to 23 Apr 77	Poirier
24 Sep 77	White Sands Missile Range, New Mexico	A10.705-1 Piaute Tomahawk	15 Sep 77 to 24 Sep 77	Marks
13 Oct 77 20 Oct 77	Chico AFB California	Balloon (BAMM) Balloon (BAMM)	28 Sep 77 to 28 Oct 77	Thorn
	Poker Flats Resch Range, Alaska	IC 719.08-1 Sergeant Hydac (No Launch)	24 Oct 77 to 4 Nov 77	Rocheport
	Poker Flats Resch Range, Alaska	IC 719.08-1 Sergeant Hydac (No Launch)	24 Oct 77 to 20 Nov 77	O'Connor
12 Dec 77	White Sands Missile Range, New Mexico	A04.602 Aerobee 170	4 Dec 77 to 13 Dec 77	Marks
27 Feb 77	Poker Flats Resch Range, Alaska	I807.15-1 IC 819.08-1 Sergeant Hydac Nike Hydac (No Launch)	21 Feb 78 to 15 Mar 78	O'Connor Marks
19 Apr 78	Holloman AFB New Mexico	Balloon (Hall)	11 Apr 78 to 21 Apr 78	Poirier
T.V. Camera Repair	Tufts University	BAMM Balloon	8 Aug 78	Thorn
Balloon Symposium	Portsmouth, NH		21 Aug 78 to 23 Aug	Rocheport Poirier
30 Sep 78	Holloman AFB New Mexico	Balloon (Hall)	12 Sep 78 to 30 Sep 78	Poirier Wheeler
26 Oct 78 12 Nov 78 No Launch	Poker Flats Resch Range, Alaska	I 807.15-1 Nike Hydac I 830.09-1A Sergeant I 807.15-2 Nike Hydac (No Launch)	16 Oct 78 to 15 Nov 78	O'Connor Marks

<u>Purpose or Launch Date</u>	<u>Location</u>	<u>Vehicle Type &amp; Designation</u>	<u>Trip Duration</u>	<u>Staff</u>
29 May 79	Holloman A.F.B. New Mexico	Balloon (BAMM)	18 Apr 79 to 14 Jun 79	Shields
26 Feb 79	Red Lake Ontario, Canada	A12.9A2, A10.802-1 Nike Orion A10.802-2 Piaute Tomahawk A12.9A-1 Nike Orion A07.712-2 Niro	8 Feb 79 to 28 Feb 79	Marks Thorn Badii
2 Aug 79 7 Aug 79	White Sands Missile Range, New Mexico	A13.702 Astrobee F A18.805 Black Brant V	19 Jul 79 to 2 Aug 79	Marks
8 Oct 79	Keesler, A.F.B. Mississippi	Balloon (BAMM)	12 Sep 79 to 13 Oct 79	Shields
Battery Discussion	Yardney Electric Co Pawcatuck, CN	BAMM Balloon	6 Nov 79 to 7 Nov 79	Shields



## CHAPTER III

### TESTING AND ANALYSIS PROGRAMS

#### A. Telemetry Components

Evaluation studies and environmental tests of certain airborne telemetry system components have been carried out under this contract. This program was started under a previous contract, AF19(605)-3506 in April 1958, continued under later contracts, AF 19(628)-2433, AF 19(628)-5410, F19628-68-C-0197, F19628-71-C-0030, and F19628-73-C-0148 and has been quite productive. In order to arrive at a comparative evaluation of commercial equipment, all major manufacturers were invited to submit certain categories of system components on consignment. The electrical and environment characteristics were then measured and evaluated, and the results classified as proprietary information and made available to AFGL and the individual manufacturers concerned. As a sufficient number of units are evaluated, Scientific Reports are issued in order that the results be made available before coming dated.

This chapter references the reports in which detailed information can be found. Complete results from this contract are contained in Scientific Report No. 1<sup>5</sup>, dated 11 January 1977 and Scientific Report No. 2<sup>6</sup>, dated 17 May 1978, and are available to authorized agencies. A chapter of each report is devoted to one of the three major categories of system components evaluated to date, namely Voltage Controlled Oscillators, VHF and UHF transmitters. Each section contains a description of the tests performed, procedures followed and a method of result presentation for these categories of system components.

Scientific Reports No 1 and 2 of the reference contract carry the test results of the specific models from each manufacturer. A total number of

components tested in each category is shown below:

Voltage Controlled Oscillators - 265

VHF Transmitters - 7

UHF Transmitters - 103

During the period of this contract a procedure was developed to enable equipment used for component evaluations to be sent to Calibration and Standards Laboratories for calibration and certification which is traceable to the National Bureau of Standards. The details described in "Research and Development Equipment Information Report"<sup>7</sup> have been adhered to and calibration of these specific equipments has been repeated every six months.

#### B. Lithium Battery Studies

The development of light weight, high energy density power sources using a lithium and sulphur dioxide electrochemical system has shown potential for utilization in very high altitude scientific balloon payloads. At altitudes above 40 kilometers the payload weight becomes an important parameter in the selection of balloon size (and therefore cost), ease of launch, and expected survivability which is a strong function of total suspended weight.

The anticipated flight of an extreme ultraviolet (EUV) instrument which has altitude requirements of 40 kilometers and more has led to the investigation of these power sources. Lithium cells have high energy densities and an excellent operational temperature range. Calorimetric measurements also indicate shelf life expectancy in excess of 10 years. Table 2 shows the relative energy densities and the operational temperature ranges for various commonly used power cells.

The batteries normally used for balloon flights are the BB-405, a silver-zinc type cell supplied by the balloon branch at Holloman AFB. These cells,

arranged in a 28v pack, weight 60 pounds. In the EUV payload three sets of cells are needed and would weigh 180 pounds. If lithium cells are used (25 ampere-hour type 660-5), the total battery weight would be 15 pounds, a reduction of 165 pounds.

Several tests were conducted on these lithium cells to determine their capability to function under severe environmental conditions of pressure and temperature. The cells were placed in a vacuum chamber and were subjected to a pressure equivalent to an altitude of 50 kilometers for 24 hours. There was no noticeable deformation or leakage noticed during or after this test.

Another test was performed to determine insulation requirements to maintain the battery pack at safe operational temperatures. The battery pack was packaged in a container made of 1 inch polyurethane foam and placed in a chamber at  $-40^{\circ}\text{C}$ . The battery was lightly loaded at 150 milliamperes and its internal temperature was monitored. After 4 hours, the temperature dropped from  $20^{\circ}\text{C}$  to  $4^{\circ}\text{C}$  and after 30 hours it dropped to  $-10^{\circ}\text{C}$ . These temperatures are well within the operational limits given in Table 2.

A final test was made aboard a high altitude balloon on 8 Sept 1976 out of Holloman AFB, New Mexico. A battery consisting of 10 type 660-5 cells was insulated and instrumented for temperature, voltage and current. This battery was remotely turned on at an altitude of 80 thousand feet and allowed to remain loaded to 0.9 Amperes for 2.5 hours. The majority of the loaded time was spent at an altitude of 96 thousand feet. The voltage remained constant between 27.75 and 28.0 Volts and the temperature dropped only  $10^{\circ}\text{C}$  from an ambient of  $20^{\circ}\text{C}$  during the 6 hour flight.

CELL TYPE	WEIGHT (OZ.)	VOLUME (IN <sup>3</sup> )	CELL VOLTAGE (VOLTS)	TEMPERATURE RANGE (°F)	ENERGY (WATT HRS)	ENERGY DENSITY (WATT-HRS/OZ)	ENERGY DENSITY (WATT-HRS/IN <sup>3</sup> )
CARBON ZINC	3.0	3.3	1.5	+20 +130	0.5	0.17	0.15
ALKALINE MANGANESE	2.2	3.3	1.5	-20 +130	2.5	1.1	0.76
LITHIUM SULPHUR DIOXIDE	2.9	3.3	3.0	-65 +165	15.0	5.2	4.6
NICKEL CADMIUM	5.4	3.3	1.2	-4 +113	6.0	1.1	1.82
SILVER CADMIUM	3.2	2.9	1.1	-40 +140	3.3	1.0	1.14
MERCURY ZINC	5.8	3.3	1.4	+32 +130	4.0	0.69	1.2
SILVER ZINC	3.0	2.9	1.5	-40 +165	4.5	2.4	1.55
LEAD ACID	6.4	3.3	2.1	-85 +150	5.0	0.7	1.52

TABLE 2. COMPARISON OF ENERGY DENSITIES

This type of cell has subsequently been used for 3 EUV flights without any failures. This cell did have a tendency to develop leaks over a period of time and approximately 6 cells out of 35 did eventually develop leaks over a period of 1.5 years. These leaks are catastrophic in that the corrosive electrolyte would erode the welded-on terminals to the point of breaking off. The manufacturer was notified of this tendency and admitted to this problem. Since then a new hermetically sealed cell has been developed. A set of these cells were purchased and have not developed any leaks over the last 1.5 years.

C. Program PERFORM

Program PERFORM was developed during a prior contract<sup>8</sup> to calculate the key performance parameters of FDM/FM telemetry systems which use the IRIG standard subcarrier set. Changes in the control card system in use with the university computer made some program rewrite necessary during academic year 1977-78. At that time an extensive program review was undertaken and certain ambiguities were removed, the complexity of input data cards reduced, and additional comment cards inserted. The re-worked program provides the same capability as before but requires less user familiarity with the underlying theory.

Program PERFORM utilizes punched card input and computes the rms carrier-to-noise power ratio as a function of the radio frequency link parameters. For a specified set of IRIG subcarriers this program also computes 4 sets of pre-emphasis schedules, carrier modulation indices, and subcarrier discriminator improvement factors. As of this writing, plans are underway to eliminate punched cards and convert PERFORM over to terminal input for compatibility with the new university VAX computer which will become operational in spring 1980.

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AF19(628)-2433	1 April 1963 Through 30 September 1966
AF19(628)-5140	1 April 1965 through 30 September 1968
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AF19628-73-C-0148	9 January 1973 through 30 April 1976
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